Universidade de Aveiro Departamento de Electrónica, Telecomunicações e Informática,
2011

José Carlos Jardim dos Santos

HOPE-W: aplicação móvel para monitorizar feridas em enfermagem

Universidade de Aveiro Departamento de Electrónica, Telecomunicações e Informática,
2011

José Carlos Jardim dos Santos

HOPE-W: aplicação móvel para monitorizar feridas em enfermagem

Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Engenharia de Computadores e Telemática, realizada sob a orientação científica do Doutor João Paulo T. S. Cunha, Professor Associado com Agregação do Departamento de Electrónica, Telecomunicações e Informática da Universidade de Aveiro e do Mestre Ilídio Fernando de Castro Oliveira, Professor Assistente Convidado do Departamento de Electrónica, Telecomunicações e Informática da Universidade de Aveiro.

o júri / the jury

presidente / president	**Doutora Beatriz Sousa Santos** Professora Associada com Agregação do DETI/UA (por delegação da Reitora da Universidade de Aveiro)
vogais / examiners committee	**Doutor João Paulo T. S. Cunha** Professor Associado com Agregação da Universidade de Aveiro (orientador)
	Mestre Ilídio Fernando de Castro Oliveira Professor Assistente Convidado da Universidade de Aveiro (co-orientador)
	Doutor António Miguel Pontes Pimenta Monteiro Professor Auxiliar da Faculdade de Engenharia da Universidade do Porto

agradecimentos / acknowledgements

Aproveito este espaço para agradecer aos meus amigos e família que sempre me acompanharam e me deram suporte no decorrer deste percurso académico, especialmente nesta última fase, a elaboração desta dissertação.

Palavras-chave Computação Móvel, mHealth, Cuidados de Enfermagem, Monitorização de Pacientes, Avaliação de Feridas, Medição de Feridas.

Resumo Existem vários tipos de feridas, como é o caso das úlceras de pressão, que requerem um acompanhamento cuidado, assim como necessitam de vários tratamentos ao longo do tempo. A disponibilização de documentação que descreva com precisão a extensão da ferida, assim como outras características, é importante para avaliar a sua evolução, mas normalmente as medições são feitas com base em métodos pouco precisos. Algumas patologias das lesões de pele, além da progressão ao longo do tempo, envolvem o tratamento em multiplas instituições de saúde da região em causa, em que, por norma, não trocam entre si informações sobre o estado da ferida. Um exemplo acontece com o tratamento de pacientes que sofrem de pé diabético.

Dentro deste âmbito, propõe-se a utilização de dispositivos móveis para documentar estas lesões nos pontos de tratamento. Usando as câmaras digitais dos dispositivos móveis é possível demarcar a área e forma da ferida. Os profissionais de saúde registam uma série de informações relacionadas com o estado da ferida, como a sua fase de evolução, o seu aspecto e o tratamento efectuado. Além disso, a forma da ferida é definida no próprio dispositivo móvel, logo após a fotografia ser tirada. Um objecto de referência é usado para definir a sua escala.

Além da aplicação móvel (HOPE-W), a solução proposta baseia-se na integração de episódios de saúde distribuídos numa rede regional de saúde já existente. Como consequência, usando o *smartphone*, os profissionais de saúde serão capazes de introduzir dados e acompanhar a evolução de uma ferida, com base num contexto que pode ser contribuído por vários profissionais de saúde autorizados. Quando comparado com outros sistemas de medição, HOPE-W apresenta níveis de precisão aceitáveis para o uso em enfermagem, significando que é um método viável na obtenção de informações de feridas.

Foram realizados testes de usabilidade com profissionais de saúde, e os resultados obtidos são bastante satisfatórios.

Keywords

Mobile Computing, mHealth, Nursing Care, Patient Monitoring, Wounds Assessment, Wound Measurement.

Abstract

Several kinds of skin lesions, like pressure ulcers, require several treatments in time and a careful monitoring. The availability of accurate documentation of the lesion extent and other properties is important to assess its evolution, but usually only approximated coarse-grain measurements are taken. Some skin-lesion related pathologies, besides spanning in time, also involve multiple care service points in the region, usually not exchanging the clinical context of the patient, as occurs for the treatment of severe diabetic foot conditions.

It this context,we propose the use of mobile devices to document skin leasing in the point of care. Using the smartphone camera it is possible to take pictures of the wound, and then demarcate the wound area and shape. Additional information about the wound appearance, evolution or performed treatment is collected. Health professional demarcate wound area and shape right after taking the photo, in the mobile device, using a reference object to define a scale.

In addition to the mobile application (HOPE-W), the proposed solution builds on the integration of distributed care episodes in an existing regional health information network. As a result, health professionals will be able to enter data and follow the wound evolution, using the smartphone, based on a context that can be contributed by several authorized professionals. When compared to other measuring systems, HOPE-W presents accuracy levels that are acceptable for the nursing practice, showing that is an viable method to extract wound information.

Usability tests were performed by health professionals, and the results are very satisfactory.

Contents

List of Figures

List of Tables

List of Acronyms

HIP Hospital Infante D. Pedro

HIS Hospital Information System

HOPE Health On Palm's Environment

HOPE+ Health On Palm's Environment Plus

HOPE-W Health On Palm's Environment (Wounds)

IIS Internet Information Services

PDA Personal Digital Assistance

RTS Rede Talemática da Saúde

SNS Serviço Nacional de Saúde

SOAP Simple Object Access Protocol

XML eXtensible Markup Language

Chapter 1

Introduction

1.1 Context and Motivation

At the present time, the healthcare environment can be seen as an information-intensive arena where a large amount of information is required allied to time critical situations. The use of technology tools, rather than pen and paper can reduce the risk of medical errors and misplaced record, improving data accuracy and the amount of paperwork [1]. Therefore, technology can be very helpful so the right data can be available to the right personal in those time critical situations [1].

As stated, the introduction of technologies tools is beneficial in the healthcare environment. Regarding this, an information system - HOPE [2] - was developed, that allowed nursing professionals to insert data as patients were admitted and first evaluated. An improvement to this system came up - HOPE+ [3] - with some extra features. As an initial part of this dissertation work, this system was redesigned and adapted to the healthcare environment of Hospital Infante D. Pedro in Aveiro.

Nowadays, with the widespread of wireless networks and smartphones, they can be used to assist healthcare professionals in their duties. High resolution cameras, high storage capability, touch screens and wireless access are some of the features that make smartphones an excellent auxiliary device in the health sector.

Usually, every healthcare unit has independent clinical records. This leads to data replication, outdated data and inputting the same information every time a patient enters in a healthcare unit for the first time.

Using mobile phones and wireless networks, it is possible to store clinical data in a centralized architecture, making clinical data accessible from anywhere, though new and demanding security and privacy requirements must be met.

Literature refers that mobile phones can be very helpful in healthcare environment. They are described as portable devices that can improve the work efficiency of ward-nursing, the accuracy of nursing work, keep nurses updated with real-time information, improving the nursing quality [4]. Mobile phones can also be very helpful in the documentation of skin wounded patients [5]. Using the camera is possible to take pictures of the wound, storing them through the wireless network. Related information about the treatment and the picture, such as wound area and shape, can be stored too. So, all this information can be accessed anywhere. This is especially useful on patients with diabetes or pressure ulcers. Taking into account that skin wounds treatment is composed by several episodes, pictures offer an excellent record of the wound evolution through time.

A private regional health information network - RTS (Rede Telemática da Saúde)[1] - was created composed by some major healthcare units in Aveiro region. RTS stores patients' clinical data, such as past episodes, allowing healthcare professionals to access patients' information in other healthcare units.

Using RTS as a backbone, it is possible to store wound related information that is accessible on healthcare units that belong to RTS. This allows healthcare professionals to follow patients' treatments without being physically present. Also, unnecessary moving is avoided by patients to do certain treatments.

1.2 RTS - Rede Telemática da Saúde

Rede Telemática da Saúde, also known as RTS, is a project that begun in the year 2004.[6] It was developed in a partnership between Universidade de Aveiro and HIP Hospital Infante D.Pedro. Health institutions, such as Hospital Distrital de Águeda and Sub-Região de Saúde de Aveiro, are also project partners. RTS purpose is to connect the healthcare units in the Aveiro region, in order to improve clinical communication and interaction between healthcare units. RTS is a telematic health network, where institutions can share clinical information. Healthcare professionals can use this network to exchange information and to patients' clinical records. If a professional is diagnosing a patient that has an history in a healthcare unit that belongs to the network, he can check patient information, which will improve diagnostic quality.

RTS makes available a selected subset of the available information in production systems, such as forms imaging exam's files. This network has more than 10.000.000 inserted clinical episodes from more than 350.000 patients [7].

1.3 Goals

As stated in the previous section, RTS is a private regional network composed by some Aveiro's major healthcare units. Institutions can use this network to access patient information.

Patients that suffer from skin wounds, such as diabetic foot and pressure ulcers, require a long treatment composed by a large number of interventions.

As RTS has control access by health professionals, and already is capable of sharing data, it can support additional features, such as wound related information.

Using this network and mobile technology, it is possible to develop a module to store skin wounded treatments information. This module would use RTS to authenticate health professionals and to list patients in the system.

Using a mobile device, healthcare professionals would be able to insert new treatments, check past treatments, see wound evolution and insert clinical data, such as photos and treatment description, while they are treating the patient. Also, health professionals would be able to review past treatments from any location, avoiding unnecessary trips by patients and health professionals.

This project's ultimate goal is to create a system that will improve wound monitoring, sustained on a reliable method to measure wounds, when compared to the traditional wound

[1] `www.rtsaude.pt`

measurement methods. Also, it will be possible to monitor wound treatment progression in another healthcare units, taking advantage of the already existing network that enables data exchange between different healthcare units in Aveiro region.

1.4 Dissertation Structure

This document is structured in seven chapters.

- **Chapter 1:** Introduction - This chapter describes the context in which this project was originated, and why this project is benefic in the specific area. Also, initial goals are presented here.
- **Chapter 2:** Review of the State of the Art - This chapter sums up the history of mobile devices and how these devices purpose changed through the years. In addition, mobile platforms are introduced and analyzed from a developer perspective. Wound measurement techniques are also analyzed in this chapter.
- **Chapter 3:** HOPE-W System Requirements - This chapter describes which problems exists in the target scope, and how this project will contribute to solve them. HOPE-W use cases are presented in detail.
- **Chapter 4:** System Design - This chapter presents the system architecture and how the system connects with other systems.
- **Chapter 5:** Implementation - This chapter describes in detail how the several modules were implemented and how they connect with each other.
- **Chapter 6:** System Validation - This chapter presents results about the system performance. Wound measurement feature was tested and usability tests were performed. Results from user tests are presented and analyzed.
- **Chapter 7:** Conclusion - This chapter presents the conclusions that were obtained after finishing this project, reviews which work was made and suggests several topics to future work.

Chapter 2

Review of the State of the Art

2.1 Mobile Devices Evolution

In current days, mobile devices can be separated in two main groups: The first one are the smartphones devices and the second one the tablet computers. But these concepts were only defined in the recent years. In this section, an overview is made about the devices that gave rise to these two widely group devices.

CASIO PF-3000 (see figure 2.1a) was the first digital diary, released in the year 1983. Its main features were, besides the calculator, holding memos, addresses, phone numbers and names.

In October 1984, Psion Organizer was announced as the "world's first pocket computer". It's main features were announced as "10K of non-volatile character storage in cartridges, two cartridge slots, a database with a search function, a utility pack with math functions, a 16-character LCD display, a clock/calendar, BASIC-like programming with the optional Science pack, and a calculator that you can edit. There are also lots of optional goodies."

The term PDA (Personal Digital Assistance) has appeared in the year 1992 when Apple introduced the Apple Newton MessagePad series [8, 9] (see figure 2.1b). These device's main features were handwrite recognition and screen orientation recognition. But the main feature that made this device remarkable in mobile devices history is the touch screen. User interaction was made with the stylus.

There is a lot of discussion about which device should be considered as the first PDA in history. Due to the lack of agreement on this subject, we can consider that these three devices are the founders of the PDA of nowadays.

1996 was one of the most important years in mobile devices development, due to the series of events that occurred. Nokia launched 9000 Communicator, the first mobile phone with PDA functionality. Also, Palm released their first PDA, the Palm Pilot, introducing Graffiti, a revolutionary input method. Microsoft wasn't left behind, and also released Windows CE operating system, developed essentially for low capacity devices, such as mobile devices.

Two years later, RIM introduces the BlackBerry 850, a pager with integration with existing enterprise email. It also could send and receive pages and act as a basic organizer.

In the year 2000 PocketPC 2000 was released. Windows CE 3.0 was used has the operating system.

In 2001, Microsoft introduces the Compaq Tablet PC, popularizing the term "tablet PC". This device's operating system was Windows XP. It was the first time a desktop oriented OS

(a) Casio PF3000 (b) Apple Newton MP100

Figure 2.1: Casio PF3000 and Apple Newton MP100

---

was adapted so it could be used in mobile devices. This device was very similar to a common laptop, with all the features of a full-size personal computer, but it had a touchable screen and a rotating monitor. This allowed users to use a stylus to interact with the operation system, without the need of a keyboard or a mouse. This tablet was oriented to be an auxiliary device in the business environment, taking advantage of the inherent portability.

In 2005 Microsoft presented Windows Mobile 5.0, a new smartphone operating system, based on the previous Windows CE.

In 2007 Apple introduced to the world a new operating system - iOS, bounded with a new smartphone - iPhone. In the same year appeared a new mobile oriented operating system named Android. One year later the first mobile device with Android OS is launched. In October 2010, Microsoft introduces Windows Phone 7, the successor of Windows Mobile operating system.

In 2010, Apple launched the iPad. This tablet uses the same operating system - Apple iOS - that iPhone uses. That was the main difference to the previous existing tablets; it was running an operating system that was specifically designed to mobile devices. This way, user experience was largely improved in the tablet segment. In the same year, Galaxy Tab was launched running Google Android. An adapted version of the smartphone OS for devices with wider screens, such as tablets.

Following the Apple's tablet enormous success, a new version was launched in 2011: The iPad 2. In the same year, Galaxy Tab also presented a new version: The Galaxy Tab 10.1, a direct rival to the iPad 2. As happened in the smartphone market, several manufactures joined the competition for the market share. RIM presented the BlackBerry playbook running BlackBerry Tablet OS and HP presented the HP TouchPad, running webOS operating system.

In current days, the dominant operating systems for mobile devices are iOS and Android (see table 2.1), both used in smartphones and tablet devices. A high-end mobile phone as the iPhone 4 (see figure 2.2a) has a storage capacity of 16 GB or 32 GB, 512 MB of memory, a multi-touch display with a 640×960px resolution and a 5MP camera. Samsung Galaxy S II (see figure 2.2b) has a 1.2 GHz dual-core Processor, 1 GB of memory, an internal storage capacity of 16 GB, a multi-touch display with an 800×480px and an 8MP camera.

A high-end tablet computer as the iPad 2 (see figure 2.3a) has a storage capacity of 16, 32

(a) Apple iPhone 4 (iOS) (b) Samsung Galaxy S II (Android)

Figure 2.2: High-end smartphones

or 64 GB, 512MB of memory, a 250 mm multi-touch display with a 1024×768px resolution and a front and back integrated camera. Samsung Galaxy Tab 10.1 (see figure 2.3b) has a storage capacity of 16 or 32 GB, 1 GB of memory, a 260 mm multi-touch display with a 1280x800px resolution and a front and back integrated camera.

Nowadays, tablet devices and smartphones share almost all features. Their main differences are the screen size and resolution, and that smartphones have phone functionality.

This kind of devices is equipped with a lot of features that can be helpful in many different situations. They were designed to be used for business and entertainment purposes. Devices can access wireless networks, have internet access, are equipped with email clients, organizing tools, Bluetooth, GPS, digitally compass, high resolution cameras, and many other features, although most users does not use most of the mentioned functions [10].

(a) Apple iPad 2 (iOS) (b) Galaxy Tab 10.1 (Android)

Figure 2.3: High-end tablets

Using the mentioned features, such as the wireless networks, mobile devices offer wide possibility of access to business information systems and even to be used as web services providers [11, 10], thus mobile devices are much more efficient and useful that is supposed or apprehended by many users [10].

2.2 Developing for Mobile Devices

Nowadays, there are several mobile platforms. The main developing mobile platforms are iOS, Android and Windows Mobile/Windows Phone 7. Although, there are other mobile platforms suitable for development purposes, such as RIM's BlackBerry OS, Samsung's Bada or Nokia's Symbian.

Like smartphones, tablets also have several platforms available in the market: iPad iOS, Android, BlackBerry, Windows and HP WebOS.

Tablets and smartphones main differences are the capability to make phone calls and the device size. When developing a mobile application, target device must have to be taken into account. Tablets great advantage it is their wider screen size, and smartphones take advantage by their greater mobility.

Global sales of mobile recording an increase of 16.5% year on year [12]. In the second quarter of 2011, according to research firm Gartner, Inc., smartphones sales have grown 74% over the second quarter of 2010. Both Apple and Google increased their operating systems market share, with combined sales of nearly 62% in smartphones sales in the quarter. Google Android was the operating system with more smartphones sold, as table 2.1illustrates.

Operating System	**2Q11** (K Units)	**2Q11 Market Share** (%)	**2Q10** (K Units)	**2Q10 Market Share** (%)
Android	46,775.9	43.4	10,652.7	17.2
Symbian	23,853.2	22.1	25,386.8	40.9
iOS	19,628.8	18.2	8,743.0	14.1
Research In Motion	12,652.3	11.7	11,628.8	18.7
Bada	2,055.8	1.9	577.0	0.9
Microsoft	1,723.8	1.6	3,058.8	4.9
Others	1,050.6	1.0	2,010.9	3.2
Total	**107,740.4**	**100.0**	**62,058.1**	**100.0**

Table 2.1: Worldwide Smartphone Sales to End Users by Operating System in 2Q11 (Thousands of Units) [12]

While iOS is a single targeted platform, since iPhone is the only target device, Google Android offers a wide range of devices, as a large number of manufactures use Google Android as the primary operating system for their devices. From low budget devices, such as the LG P-500, to the Samsung Galaxy II, a high-end phone, there are a lot of options available in the market.

Low-end devices, such as the Android's LG P500, are also equipped with the most important features that high-end devices have, such as wireless access, internet access, touch screen or integrated camera. The main difference between these two segments is the hardware quality and not the amount of features available. Screen size and resolution, processor capacity, memory capacity, and available storage are the main features that high-end devices gain great advantage when compared to the low-end devices.

Summing up, Android holds the largest smartphone market share, and, unlike iOS, presents a large range of available devices. Also, low-end devices are equipped with the most important features and most mobile applications work properly on those. For the mentioned reasons it is plausible to say that, in these days, Android is the most suitable development platform.

2.3 Review of Mobile Enabled Nursing Applications

With the evolution of mobile devices and wireless environments in the past years, a particularly section of eHealth has appeared: mHealth. mHealth can be defined as "emerging mobile communications and network technologies for healthcare" [5]. Telemedicine refers to the capability to deliver health information and services through separate locations. It can be segmented in two main models: interactive video and store-and-forward [5]. The main difference between these two methods is that the first one allows real-time patient care, and the second one is asynchronous. For instance, a videoconference call between a clinical professional and a patient fits in the first model. Using a mobile application to collect patient information and store it in a data server so another health professional can access it later is an example of a store-and-forward model [5].

From another perspective, mobile application can be divided in two groups: Applications used by health professionals such as nurses or doctors, and applications used by regular persons to auto-management purposes.

In the past years, patient self-management tools gained relevance [13]. As stated, these are applications that are used by non-clinical persons to manage or control their health or healthcare. The growth of this kind of application is caused by the public health initiatives in areas such as the obesity and smoking [13]. Besides that, the increase of smartphone users and available applications also boost the number of these applications users. Furthermore, applications can be easily obtained from online stores like Android Market or iPhone's AppStore. Clinical professionals can install all these available applications in their own devices.

A lot of mobile solutions have appeared in the past years. A large part of mHealth solutions are related with the *biomonitoring* concept, i.e., the monitoring of parameters as heart rate, blood pressure, blood oximetry and other physiological signals. [5]

Nurses identified the main benefits of using PDAs in clinical practice as "having quick access to a current drug database and nursing reference books ... ability to manage patient and procedure information ... bedside data entry ... data collection for research and teaching ... and improved team communication" [14, 15].

Also, newly graduated nurses usually feel unsure of their skills, and insecure about their knowledge level, and lack self confidence. Therefore, the use of tools such as smartphones can improve the quality of education, performance and patient care [15].

Studies were taken [16] on an academic health sciences campus to determine how nursing students used PDAs. The most used features were simple applications, such as the calculator and the date book. Drug databases were also highly used by the test subjects, revealing that mobile devices can be used as an auxiliary memory aid.

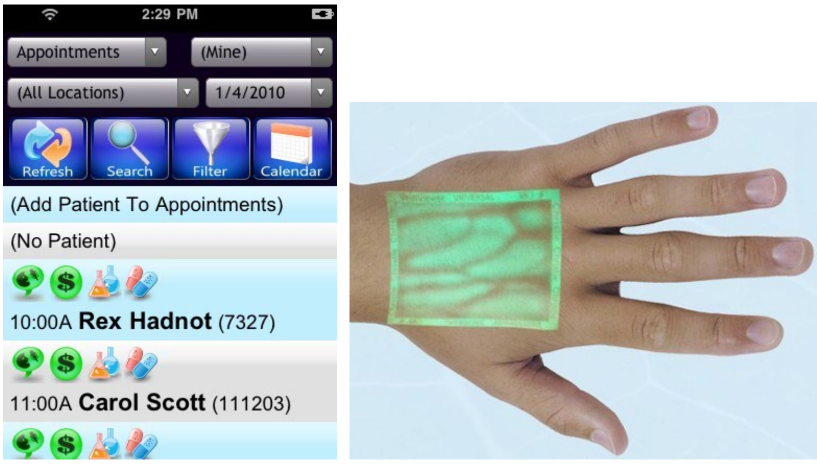
Regarding this, there are many available mobile applications to help clinical personal in their daily duties. The most common mobile applications are clinical references, such as drug manuals, drug calculators, tools to facilitate analysis of lab and diagnostic studies, and differential diagnosis guides [17].

Taking into account that these are mobile applications, nurses can consult desired information in any location. By doing that, they are saving time, which is very important in time critical environments as the healthcare environment is. Also, accessing these references means that the nurse is consulting updated data, as most mobile applications offer constant updates [17].

As stated before, there are a large number of applications that act as drug manuals, drugs calculators or tools to facilitate patient diagnosis.

Besides that, there are applications designed to improve and manage health professionals' daily duties. For instance, IQPatients (see figure 2.4a) is a mobile application aimed for clinical professionals. Using wireless networks, health professional can access demographic information, census list and manage a personal schedule integrated with patient information.

Other mobile applications have a more direct use in clinical practice. VeinViewer (see figure 2.4b) and AccuVeinAV300 [1] use infrared technology to locate subcutaneous veins. Images are projected onto the surface of the skin.



(a) IQPatients Screenshot (b) VeinViewer Screenshot

Figure 2.4: Nursing mobile applications [a]

[a]taken from (a) http://www.iqmax.com/solutions/iqpatients-mobile-patient-schedule/ and (b) http://www.christiedigital.com/en-us/medical/pages/default.aspx

2.4 Wound Measurement

One of the most important features in HOPE-W system is to keep a record of the wound evolution. System is able to store wound size, height, width, area and shape. Wound measurement is a very important aspect in clinical treatments, so it is the chosen method to perform this action. Literature refers that the use of primitive techniques in wound measurement can introduce errors as much as 40% [18].

In this section, several wound measurement methods are analyzed, presenting the main advantages and disadvantages.

There are several techniques to measure skin wounds. The purpose of any wound is to monitor the progress of healing through changes in the length, width, area or volume of a wound [19].

The simplest and cheapest method to evaluate the wound surface is to use a ruler to note down their linear measures, such as height and width. "The most common method of

[1]http://www.accuvein.com/

determining wound area is to measure the longest length and width, regardless of head-to-toe orientation, or to measure length and width perpendicular to one another" [20]. Then, wound area is obtained multiplying wound length and width. "The major problem with multiplying these 2-dimensional measurements is that the area estimated is either a rectangle or square, depending on the measurements. If the L and W measurements closely approximate one another, the area calculated would be roughly equivalent to a square, whereas different L and W measurements multiplied together roughly equate to the area of a rectangle." [20] Also, area can be estimated assuming that the wound has a circle, an oval shape (maximum diameter $\times$ maximum diameter perpendicular to the first measurement) or even using the ellipse formula (length $\times$ width $\times$ 0.785) [19]. This technique is simple and convenient but unreliable for large or irregular wounds, as the result area is larger than the actual wound area [20, 21].

At Hospital Infante D.Pedro, partner in the development of the project, wound measurement is made by using a ruler to note down wound width and height. Wound area is not registered.

An alternative is the tracing or planimetry method. The health professional traces the wound perimeter onto a transparency and uses a metric grid to count the squares that are within the wound perimeter. This method has several disadvantages: it is time consuming, especially if the wound is large [22], it can cause discomfort drawing the perimeter and error arises in the decision of including partial squares in the wound.

Visitrak Wound Measurement System [23] (see figure 2.5) is other device that was designed with the purpose to measure wounds. A layered grid is placed around the wound and the clinical draws the perimeter with a stylus. Then, the layered grid is placed in the device, so the system can analyze the perimeter and feedback user with the wound progression. The main problem with this kind of systems is their elevated price.

Figure 2.5: Visitrak System [a]

[a]taken from `http://www.medicalplus-pt.com/catalogo.php?pag=produto&id=3393`

Other techniques consist in taking photos, and then use software to calculate wound extension. As this method avoids any physical contact with the wound, any chance of wound discomfort is eliminated, being this a great advantage of this method [24]. Also, it is referred in literature [24] that this technique has not demonstrated significant statistic difference with methods similar to the Kundin device, which is stated further ahead.

All previously referred wound measurement techniques work in a two dimensional plan. Thus, only wound area, length and width are collected, unlike wound depth and consequently, wound volume. Studies were made to evaluate the precision error of two dimensional measuring techniques [25], as shown in figure 2.6.

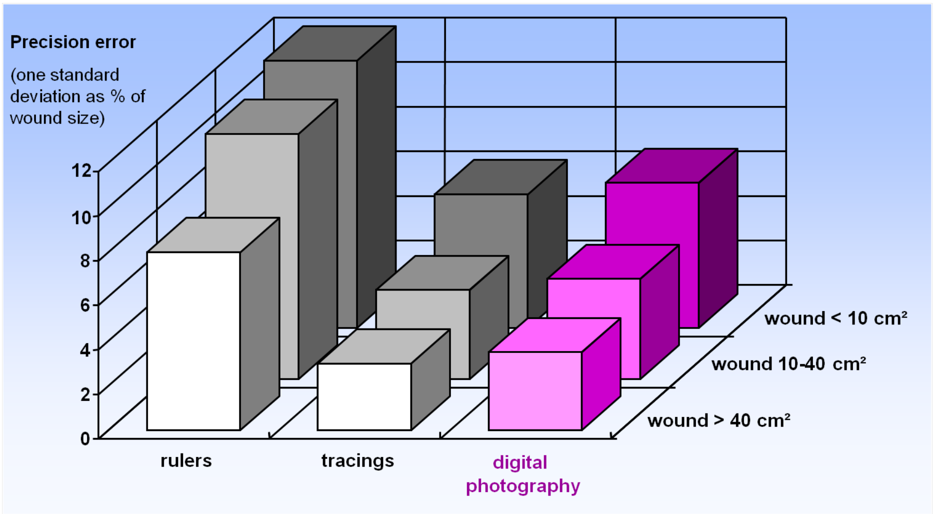


Figure 2.6: Precision of 2D Measurement Techniques [25]

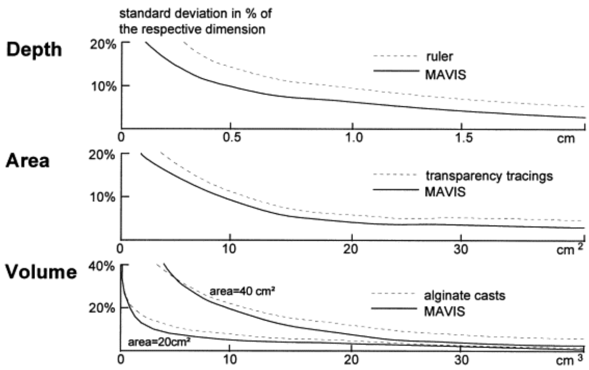


Figure 2.7: Precision of measurement methods on wound models [25]

Studies show that the use of rules to measure the wound is the method that introduces the largest precision error, whatever the wound size is. Besides that, digital photography appears as a reliable wound measurement technique [25].

Wound measurement techniques can be segmented into two categories. The first one is the two dimensional wound measurement techniques, which were previously described. The second one is the three dimensional wound measurement techniques, which will be described ahead.

There are two main techniques to measure wound volume. The first one is to fill the wound with saline: The volume is calculated based on the amount of liquid that was dispensed from the syringe. This method's main problem is that the skin can absorb the liquid, increasing the amount of dispensed liquid, and consequently, the estimated wound volume. The second method is to fill the wound with an alginate or silicone based paste: The volume is calculated based on the amount and weight of material used [25]. This method's main problem is that the patient can feel uncomfortable or pain, since the device contacts directly with the wound.

To improve measurement accuracy, there are devices that were designed with the single purpose to measure wounds. One example is the Kundin device [26]. It is a disposable, 3-dimensional, plastic-coated paper wound gauge. Device producers suggest that clinicians may use only the length and width measures when using the device. It is inexpensive and takes minimal time to use. However, this device has a downside, it can cause pain when placed in the wound [22].

A more sophisticated method is to use a mobile device equipped with a laser digitizer. An example is the ARANZ Medical Silhouette Mobile [27, 28] (see figure 2.8), which has a scanner head that attaches to a standard Personal Digital Assistance (PDA). The scanner comprises a digital camera used to capture an image of the wound and structured lighting that includes 2 fan laser beams [28]. The health professional points the camera to the target wound and a photographic image of the wound is taken, then he or his traces the wound perimeter. After that, a second image is recorded using the laser beams, to obtain wound depth. Based on this measurements, system computes wound volume. When humans measure a distance, there is always an associated error to the final value. Since it is the device that retrieves wound measures, human error is minimized.

Figure 2.8: ARANZ medical silhouette mobile [a]

[a]taken from http://entechealth.com/silhouette

This method's downside is the cost evolved in the acquisition of these devices.

MAVIS-II [29] (see figure 2.9) is another wound measurement system that can retrieve 3D images of the wound. The MAVIS 3D camera captures 2 simultaneous images. Images are shoot from different angles so wound depth can be calculated comparing the displacement between the two images. Then, in a computer, the health professional draws the wound perimeter with the computer mouse. With this information, MAVIS calculates a wire mesh map of the wound area. Lastly, the wire mesh can be rendered and animated so that the wound can be inspected.

As studies were made to evaluate the precision error of two-dimensional wound measurement techniques, studies were also made to evaluate the precision error of three dimensional measuring techniques [25], as shown in figure 2.10.

Figure 2.9: MAVIS-II [a]

[a] taken from http://www.comp.glam.ac.uk/pages/staff/pplassma/MedImaging/Projects/WOUNDS/MAVIS-II/INDEX.HTML

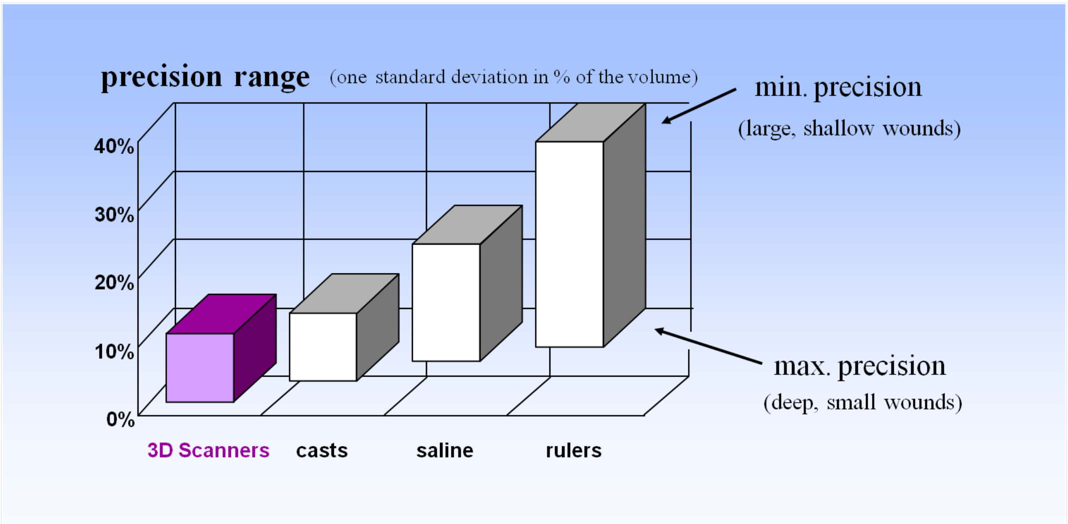


Figure 2.10: Precision of 3D Measurement Techniques [25]

Studies show that devices that use 3D scanners to measure wounds, such as the ARANZ Medical Silhouette Mobile and the MAVIS-II, present the best results. Once more, the use of primitive techniques, such as rulers, presents the worst results[25].

Chapter 3

HOPE-W System Requirements

3.1 Problem Statement

Generally, skin lesions such as skin ulcers take a long time to heal. Therefore, it is important to track the wound evolution to know how the wound is reacting to the treatment. Wound area is a very important value to analyze wound healing phase, so caregivers can know if the wound is evolving or retracting. Also, in some occasions, wound treatment requires a large number of interventions by the caregivers, almost in a daily basis. This requires numerous trips by the patient to the healthcare unit to be observed and receive treatment.

As stated in the previous chapter, there are many wound measurement techniques. For instance, health professionals in Hospital D. Pedro use rulers to measure wound length and wound width, but wound area is not saved. Wound images are also not saved, so only textual information is stored about the applied treatments and the wound progression.

It is very important that wound and treatment information can be well documented. For instance, a health professional that is about to perform a treatment in a particular patient for the first time needs the maximum background information to decide properly which actions will be taken. Thus, it is of major importance to store the most possible information about wound treatments and evolution, so healthcare givers can make the best decisions towards patient welfare.

Another consideration is how this information is stored. Generally, healthcare units have independent patient records. Also, they only share a small amount of information, when asked. Thus, when a patient receives treatments in a new health institution, not all background information is available. If information is accessible anywhere, patients can receive treatment in any healthcare unit, as healthcare professional could access all patient past records.

Storing clinical information in a single data server in a network that connects all healthcare units prevents data replication, and most important, patient clinical history is available from any healthcare unit in the network. This allows health professionals to consult patient records as they had been treated in the same health care unit, so patients can do the treatments in different healthcare units.

When saving clinical records, it must be taken into account which information is relevant. Data server will have to store wound related clinical information in order to response properly to the system requirements. System will have to store health professional and patient information. This will allow health professionals to log in the system, and to see patient information. Also, it will be possible to identify the health professional that made each single treatment, thus it will be possible to know who was the responsible for each data insertion in the system. Patients can have multiple wounds including wounds that are not being treated at this time, so system will have to manage all patient wounds so health professionals can easily access the desired wound. As stated before, wound treatment is a process consisting of several episodes, so system will have to manage all episodes for each wound.

In each episode wound related information is collected, so system must be able to properly store all gathered information. In each episode the following data must be collected and stored in the system:

- Wound dimensions: length, width and area
- Wound shape and perimeter
- Wound photo
- Surrounding skin description
- Sensibility description
- Existing tissues description
- Exudate description
- Healing phase
- Applied treatment

Table 3.1 lists and describes actors that take action in the system.

Actor	Description
Health Professional	Subject that uses the system. It could be a nurse, doctor or other healthcare related professional.
HIS	Hospital Information System - Data server that stores all system data, such as evaluations, appointments or patients history.
RTS	Rede Telemática da Saúde - Private network with medical information. This network is used to fetch patient data and to authenticate health professionals.

Table 3.1: HOPE-W system actors

Before describing each use case, a global workflow will be presented, as pictured in figure 3.1.

General workflow can be divided in two main phases: data insertion, and data visualizing or editing. Mobile environment is responsible for data insertion, and desktop environment is responsible for data retrieval.

When a health professional is attending for the first time a patient in a wound related case, logs in the system and searches the patient in the system by his or her SNS number. As it is the first time the patient receives treatment, health profession creates a new wound record by identifying the wound position in the human body. After identifying target wound, health professional takes a photograph of the wound. After accepting the photo, he defines

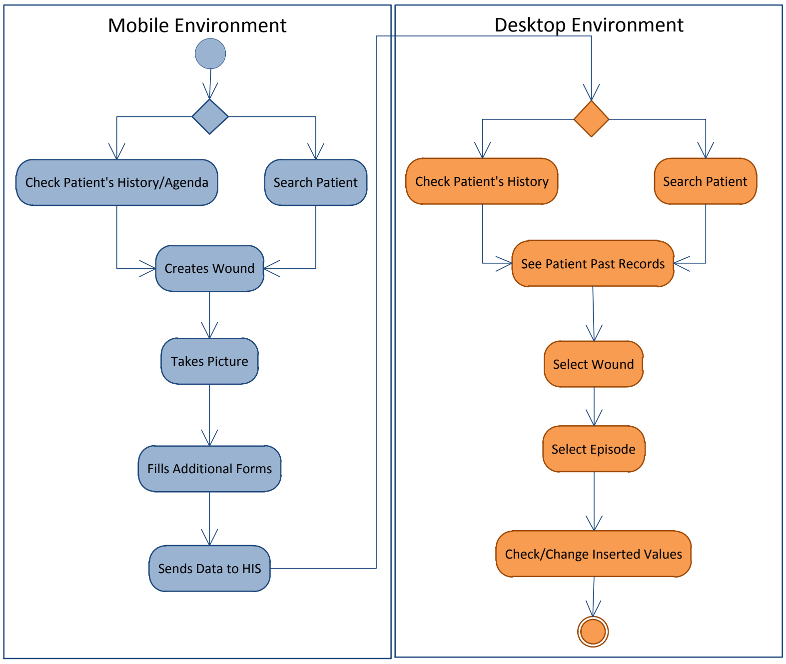


Figure 3.1: System General Workflow

---

wound shape and system calculates wound area, width and height. Additional wound related information is inserted in the system and sent to HIS server. The health professional can now review information sent by consulting patient gallery.

After data has been stored in HIS server, desktop environment use cases can begin.

Now, any health professional in a healthcare unit belonging to the network can perform the following workflow. This is one of this system's main advantages. It is possible for a patient to be treated in one facility while being monitored by another health professional in another facility through the RTS. Health professional selects the patient that was target of evaluation. If it is the same health professional that performed the evaluation, patient will be available in recent history, otherwise health professional can search the patient by the SNS number. System will present patient information and the list of wounds. After selecting a wound, a health professional is able to see all treatments for each wound. He can select a single episode to see wound details that were inserted in the system. If health professional finds relevant to change episode information, he can edit and update data in HIS server. Finally, it is possible to make a medical appointment with the selected patient. Health professional defines in which day it will occur.

When that health professional logs in the mobile application in the chosen date, patients that have an appointment with him or her are displayed. So, health professional can easily select the patient that will receive treatment.

The diagram in figure 3.2 describes the system's use cases.

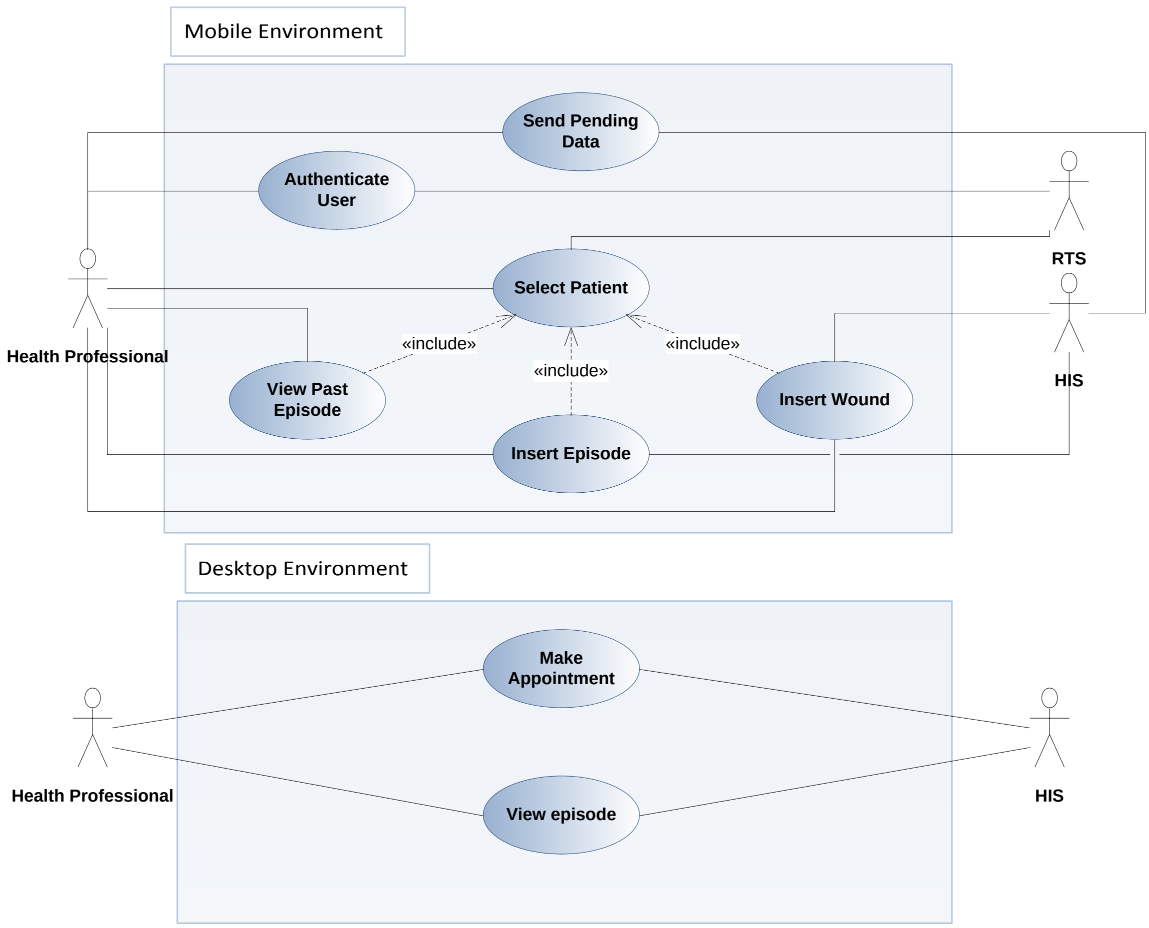


Figure 3.2: HOPE-W Use case model

3.2 Supported Use Cases

3.2.1 Insert Episode

This use case will occur when a health professional wants to submit an evolution in a wound or wants to report a new wound. Health professional fills HOPE-W forms, relative to the patient's wound. Data input includes medical information such as wound photo, wound perimeter and area, skin description and bandage type, among others. Data (evaluation report) is sent to the Hospital Information System (HIS).

Preconditions

- Health Professional must be logged in the system.
- A connection to the HIS network must be active.
- Target patient must have at least one wound inserted in the system.

Basic Sequence Events

- **{Select Patient}** Use case "Select Patient" is executed.
- **{Select Wound}** Use case starts when the health professional selects which wound will be subject of evaluation.
- **{Take Picture}** Health professional takes a picture of the wound that is subject of treatment.
- **{Define perimeter}** Health professional defines wound perimeter drawing a line surrounding the wound.
- **{Fill Forms}** Health professional fills up a form that is divided in three stages.
- **{Fill Episode}** Health Professional completes this use case.
- **{Send Episode}** Health Professional sends data to server.

Sequence Diagram

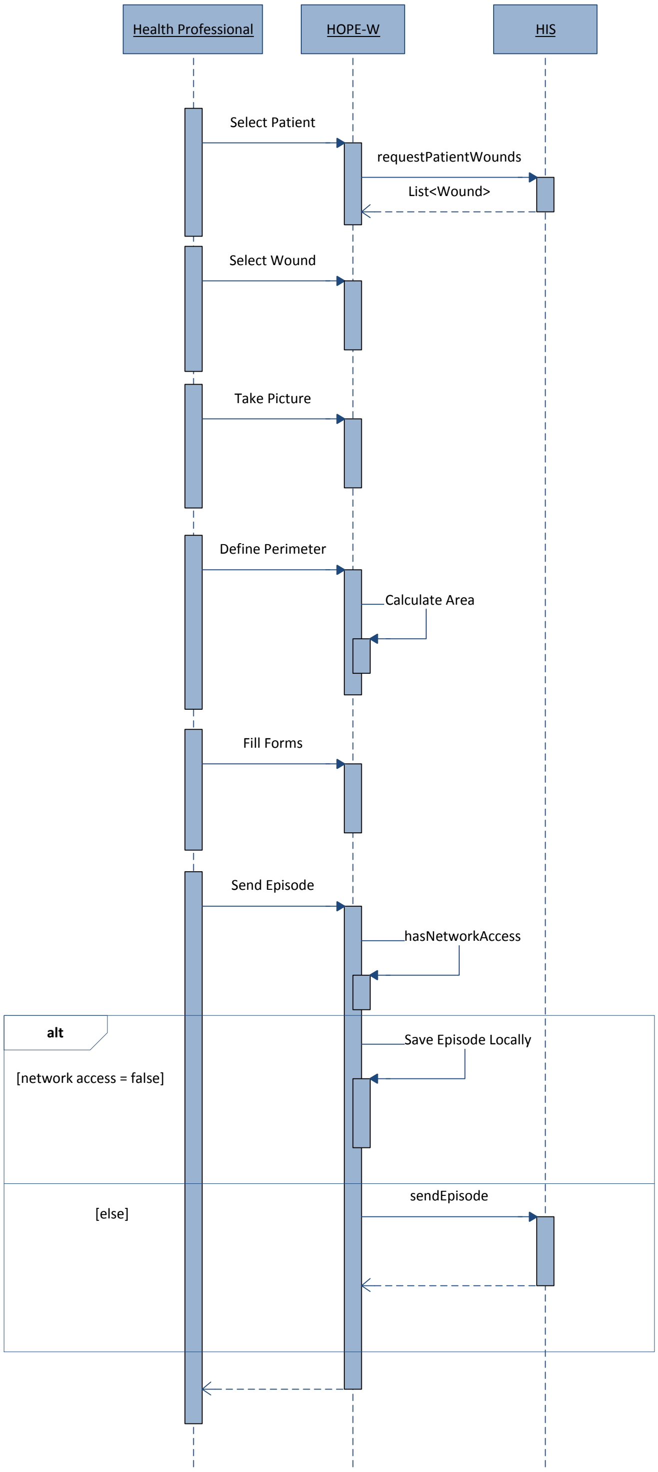


Figure 3.3: Insert Episode Sequence Diagram

Alternatives Sequences

Wireless network unavailable

When user tries to send data to HIS server and the wireless network is unavailable:

HOPE-W prompts user with the question “Network unavailable. Do you want to save data locally?”

User presses “Yes”.

Data is saved locally.

3.2.2 View Past Records

This use case occurs when the Health Professional consults an evaluation report that was previously sent to HIS server.

Preconditions

- Health Professional must be logged in the system.
- Target mobile device must have sent at least one evaluation to HIS Server.
- Target patient must have at least one wound inserted in the system.

Basic Sequence Events

- **{Select Patient}** Use case “Select Patient” is executed.
- **{Select Wound}** User selects target wound.
- **{View Past Evaluations}** User presses button “View patients’ photos”
- **{Define perimeter}** Health professional defines wound perimeter drawing a line surrounding the wound.
- **{Select Evaluation}** System shows a gallery with all the past evaluations sorted by date. User selects one evaluation.
- **{View Details}** User presses photo to retrieve treatment specifications.

Sequence Diagram

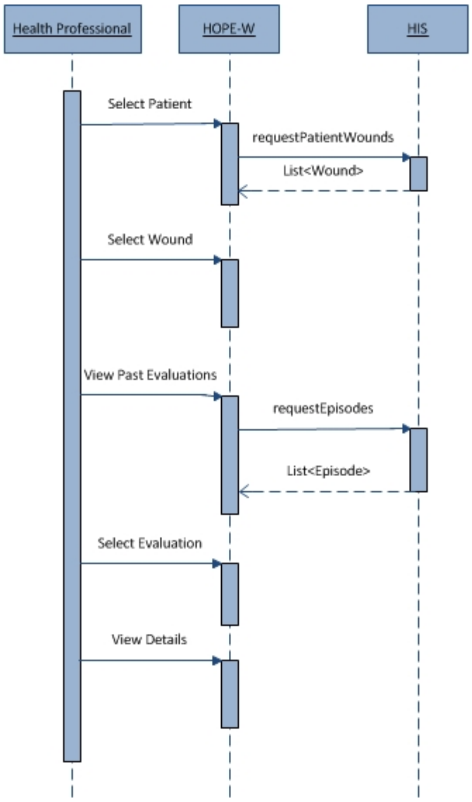


Figure 3.4: View Past Records Sequence Diagram

3.2.3 Send Pending Data

If there are evaluations stored locally in the mobile system, user can upload them to HIS server.

Preconditions

- Health Professional must be logged in the system.
- A connection to the HIS server must be active.
- System must have evaluations files stored locally.

Basic Sequence Events

- **{Select Patient}** Use case "Select Patient" is executed.
- **{Select Wound}** User selects target wound.
- **{View Past Evaluations}** Health Professional presses the "View Patient Photos" button.
- **{Select Evaluation}** User selects target photo.

- **{View Details}** User presses the image. Attached information is displayed.

3.2.4 Search Patient

This use case occurs when the health professional uses the search box to retrieve patient information.

Preconditions

- Health Professional must be logged in the system.
- A connection to the HIS server must be active.
- A connection to the RTS must be active.

Basic Sequence Events

- **{Insert SNS Number}** Health Professional inserts patient's SNS number in the search box.
- **{Search Patient}** Health Professional presses "Search Patient" button.
- **{Retrieve Patient}** Patient information is retrieved from RTS.
- **{Add Patient to DB}** Patient record is inserted in HIS database.
- **{Retrieve Patient}** HIS sends patient details to HOPE-W.
- **{Display Patient Info}** HOPE-W displays patient menu, which includes information about the searched patient.

Sequence Diagram

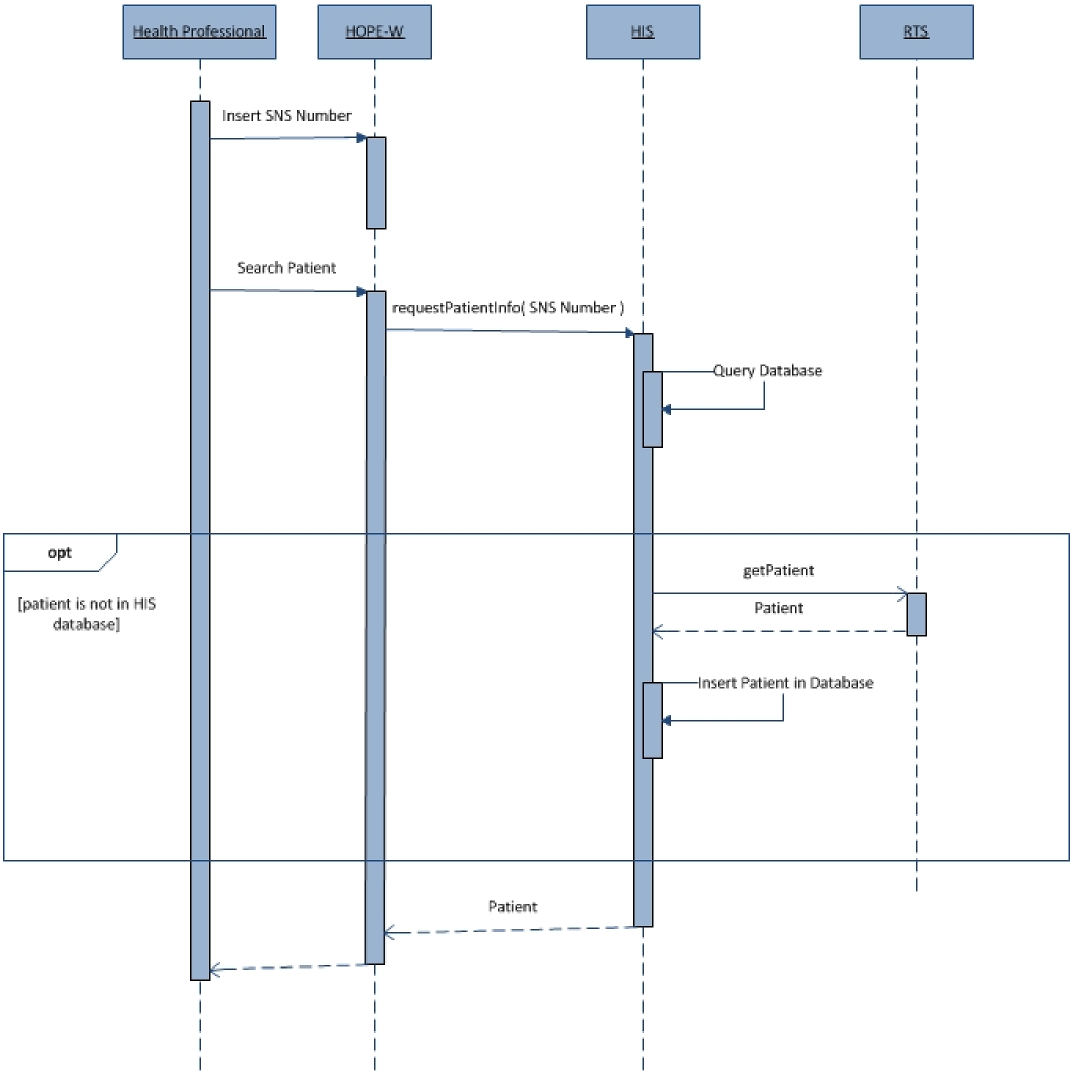


Figure 3.5: Search Patient Sequence Diagram

Alternatives Sequences

SNS number not found

If SNS number does not match any record in HIS database or in RTS database, use case ends. User is notified that there are no patients in the systems.

3.2.5 Authenticate User

This use case happens when the Health Professional starts the mobile application and enters his credentials.

Preconditions

- A connection to the RTS must be active.

Basic Sequence Events

- **{Input health professional mechanographical number}** User inputs RTS credentials.

- **{Input health professional secret password}** User inputs RTS credentials.

Sequence Diagram

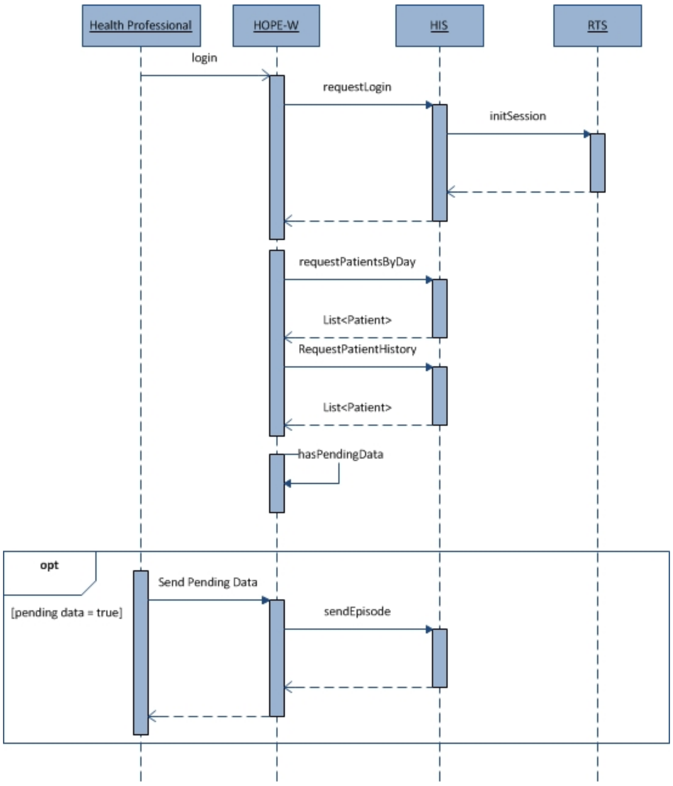


Figure 3.6: Authenticate User Sequence Diagram

3.3 Desktop Module

As previously stated, HOPE-W focus is to gather clinical information and store it in a data server (HIS), which is accessible to all the health units inserted in the private network. Mobile devices take great advantage gathering data due to their mobility and flexibility. Health professionals can use them while evaluating the patients, not being restricted to a single location in the healthcare unit.

When a health professional wants to view or edit the information that was inserted in the system, a desktop module solution is more efficient. So, HIS server information is accessible through a website.

This website design and development does not belong to this dissertation scope. This topic will be studied and presented in a different dissertation. Although, website is occasionally referred, because HIS server was designed taking into account the website requirements. A quick overview will be presented about the website requirements.

HOPE-W system would not make sense without this website. This website can be seen as a gate used by all the healthcare units to access wound related information that could be inserted in a different facility. It can be interpreted as a RTS extension conceived only to manage wound related information of patients.

Desktop module main requirements consist of properly displaying the information that is accumulatively stored in HIS server. Also, health professionals must be able to edit the stored information.

Besides retrieving and editing previously inserted data, the desktop module has some extra features. When a patient no longer needs treatment, health professionals must be able to close a wound process, disabling that specific wound option in the mobile application. When a clinical wants to appoint a new treatment in the agenda, it can be made through the desktop module.

Chapter 4

System Design

4.1 System Integration with Existing Systems

The scheme presented in figure 4.1 describes the physical deployment of the system.

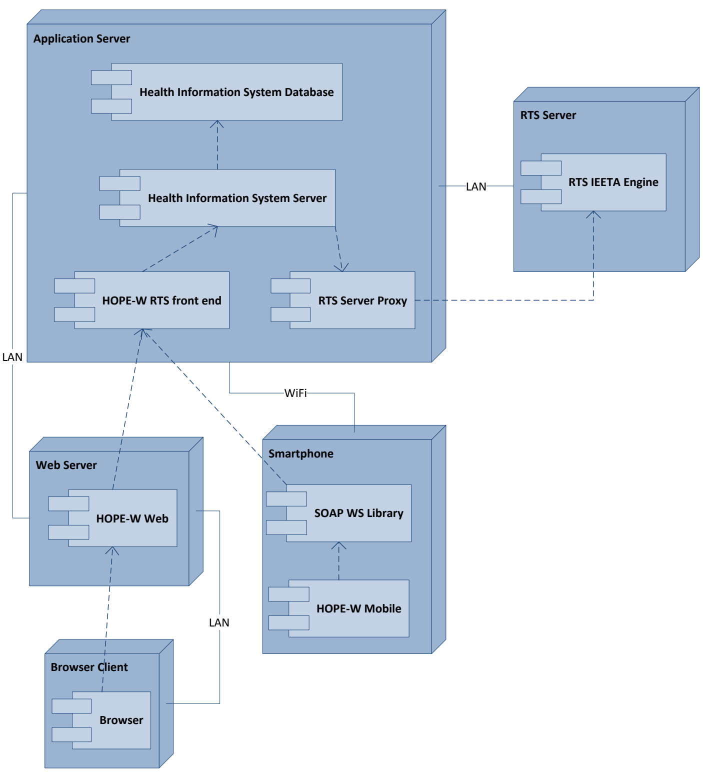


Figure 4.1: HOPE-W Component Diagram

Application Server is the central point of this architecture. It is composed by two separate applications and one database. RTS server proxy is used to consume RTS server web services and make them available to HIS Server, providing a new interface to the RTS web methods. Application server also provides a front end with web services to be consumed by the mobile application and the web server. HIS Database contains all system information, such as patient and health professional records, patients' episodes and wound pictures.

HOPE-Wounds-Web is the web server. It supports HOPE-Wounds website, which is used by HOPE-Wounds-Web browser terminal clients. Along with HOPE-W mobile application, it consumes HIS web services.

This system has two client types, mobile clients and desktop clients.

HOPE-W Mobile is the mobile client and uses the wireless network to connect with HIS server, so web services can be consumed. **HOPE-Wounds-Web clients** are desktop terminals with a web browser so health professionals can access HOPE-Wounds website, and use cable network to establish connections.

There is no limit of clients connected to the system, so any number of mobile devices can be included in the system. The same occurs with HOPE-Wounds-Web clients.

RTS defines which are the system users, that is, only patients and health professionals present in the RTS are allowed to use this system, because RTS provides patient and health professional information, so HIS database can be populated. Regarding this, RTS provides authentication to system users, as health professionals use RTS credentials to login in the system. Patients that are not inserted in HIS database are looked up in RTS, and then added to HIS.

4.1.1 Information View

HIS Database Model

HIS uses a SQL Server database (see figure 4.2) to permanently store the information the system gathers. HIS must store all patients and health professionals that use the system, so health professionals can log in the system and new episodes can be associated to patients. Besides patient information, database has to store all wounds and treatments that every patient has. Besides that, it is possible to store appointments between patients and health professionals.

Patient (see table 4.1) is a system actor, as described previously. Since patient information is retrieved from RTS, patient data model was maintained, which means that the entity "Patient" is the same in the HIS and in the RTS namespace. Since RTS model allows multiple phone numbers and multiple emails, those tables were also replicated. In this table are inserted all patients that are target of an evaluation in this system.

Patient's primary key is the SNS. SNS represents the Portuguese National Health Service number, thus it is a unique identifier in Portugal scope.

Patient's foreign keys are *RefIDEmail* and *RefIDPhoneNumber*, which allows patients to have any number of emails and phone numbers associated.

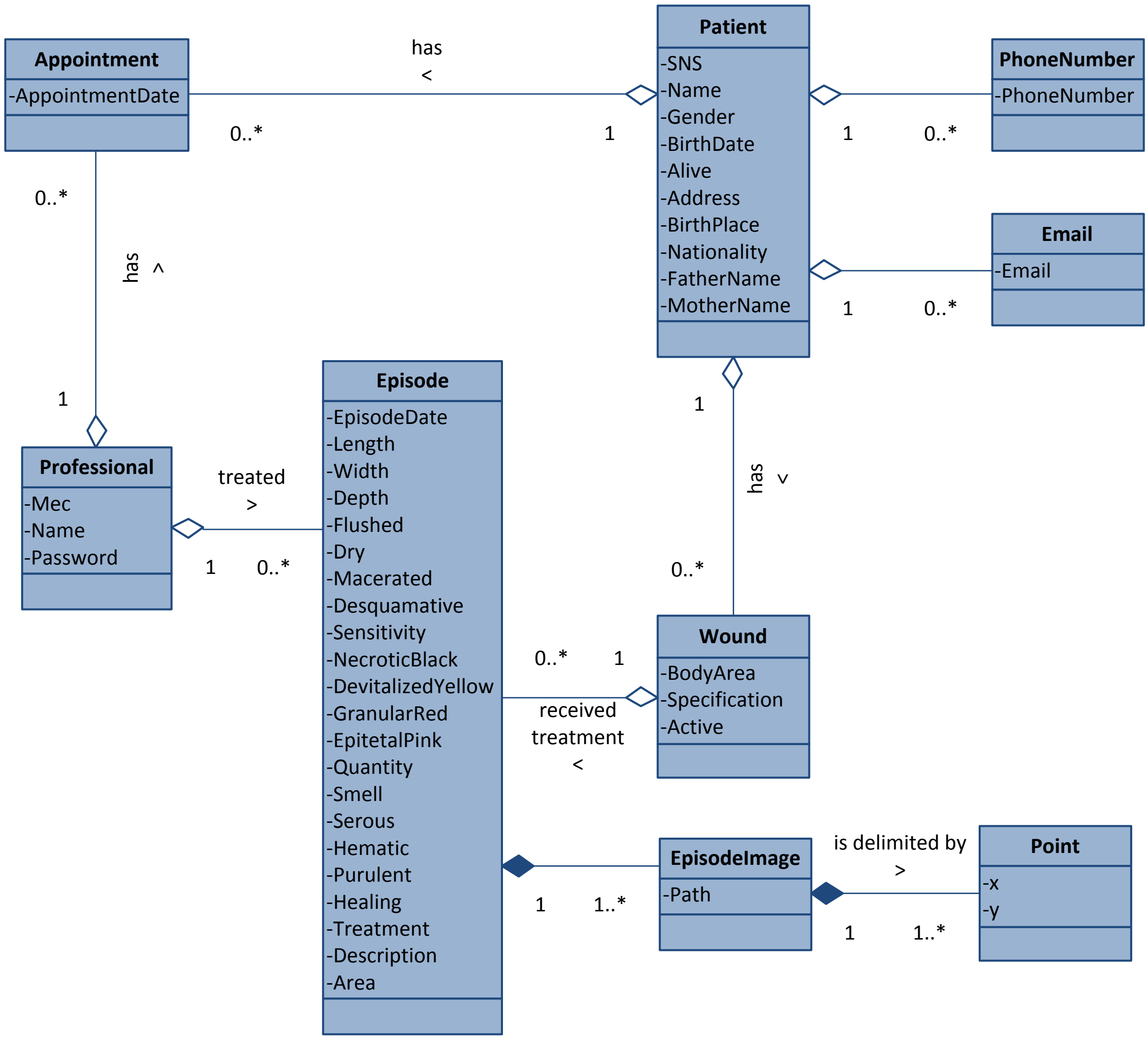


Figure 4.2: HIS Database Model

Table 4.1: Patient table attributes

Name	Patient's complete name.
Gender	Patient's gender. It could be 'M' (male) or 'F' (female).
BirthDate	Patient's birth date.
Alive	Boolean value to describe if the patient is still alive.
Address	Patient's address.
BirthPlace	Patient's birth place.
Nationality	Patient's nationality.
FatherName	Patient's father name.
MotherName	Patient's mother name.

Professional (see table 4.2) is a system actor, described as Health Professional. Health professional unique identifier is a combination of his or her mechanographical number with the institutional identifier. Since this aggregation forms a non-numerical identifier, it is not used has the primary key.

Professional's primary key is an auto-generated number denominated as *IDProfessional*.

In this table are inserted all health professionals that logs in the system.

Table 4.2: Professional table attributes

Mec	Health Professional unique identifier. It is a combination of his or her mechanographical number with the institutional identifier.
Name	String that Health Professional uses to login the system. It matches professional name that is inserted in the RTS.
Password	Password used by the Health Professional to log in the system.

Wound (see table 4.3) lists all skin lesions that patients have in the system. Every wound is associated to a single patient, which is the person that has this wound.

Wound's primary key is an auto-generated number denominated as *IDWound*.

Wound's foreign key is *RefIDPatient*, which identifies the patient that has this wound associated. This allows patients to have multiple wounds.

Table 4.3: Wound table attributes

BodyArea	Enumerator that identifies the body zone in which the wound is located.
Specification	Optional field used to store additional information about the wound. It will contain a value if the health professional felt the need to specify something about the wound, in addition to the previous attribute.
Active	Boolean field that identifies if a wound is still active. When a wound is created, wound status is active by default. If a wound does not need more treatments, it can be closed. If closed, wound status becomes *false*.

Episode (see table 4.4) contains all the information about a single treatment when a patient is evaluated by a heath professional. Every Episode has an associated Professional, which is the health professional that evaluated the patient and inserted that record, thus it is possible to know who the evaluator for every episode was in the system. Furthermore, every Episode is connected to a single Wound, which means that for each wound there is a list of episodes, representing the number of treatments that patient had for that particularly wound. In other words, a patient can have any number of wounds, and a wound can have any number of episodes.

Episode's primary key is an auto-generated number denominated as IDEpisode.

Episode's foreign keys are *RefIDProfessional* and *RefIDWound*.

Table 4.4: Episode table attributes

EpisodeDate	Timestamp representing the time this episode was created in the mobile application.
Length	Wound length.
Width	Wound width.
Depth	Although the mobile application does not collect this attribute, it was maintained, since it is a common used value in wound measurement.
Flushed	Boolean value to describe if the skin is blushed.
Dry	Boolean value to describe if the skin is dry.
Macerated	Boolean value to describe if the skin is macerated.
Desquamative	Boolean value to describe if the skin is desquamative.
Sensitivity	Describes how sensitivity the skin is.
NecroticBlack	Boolean value to describe if the skin appearance color is necrotic black.
DevitalizedYellow	Boolean value to describe if the skin appearance color is devitalized yellow.
GranularRed	Boolean value to describe if the skin appearance color is granular red.
EpitetalPink	Boolean value to describe if the skin appearance color is epitetal pink.
Quantity	Describes the exudate quantity in the wound area.
Smell	Describes the exudate smell in the wound area.
Serous	Boolean value to describe if the exudate is of the serous kind.
Hematic	Boolean value to describe if the exudate is of the hematic kind.
Purulent	Boolean value to describe if the exudate is of the purulent kind.
Healing	Describes the healing phase of the wound.
Treatment	Describes the treatment that health professional has applied in the wound.
Description	Optional field with additional information that health professional finds relevant about this single episode.
Area	Wound area.

EpisodeImage (see table 4.5) contains information about the images that are inserted in the server. Each record in this table matches a single picture that is stored in the server directory file system. For each image there is an associated Episode, which allows the insertion of several images for each episode. EpisodeImage's primary key is an auto-generated number denominated as *IDEpisodeImage*. EpisodeImage's foreign key is *RefIDEpisode*.

Images are stored in the file system. This decision was made regarding aspects such as system scalability. If images were stored in the database, system overhead would increase, especially with large amounts of data. This way, images can be stored in any location, like a different server, that could provide better performance.

Table 4.5: EpisodeImage table attributes

Path	Location where the inserted photo is stored in the file system.

Point (see table 4.6) stores the list of points that represents the overlay that defines wound borders.

Measurement is performed using two-dimensional methods, so points are defined with a pair of values: x and y coordinates.

Point's primary key is an auto-generated number denominated as *IDPoint*.

Point's foreign key is *RefIDEpisodeImage*.

Table 4.6: Point table attributes

x	x coordinate value.
y	y coordinate value.

Appointment (see table 4.7) stores the list of appointments between health professionals and patients, stating whenever health professionals and patients will have interaction. Appointments are not connected to episodes or wounds so health professional can schedule appointments without prior knowledge of wound details.

Appointment's primary key is an auto-generated number denominated as *IDAppointment*.

Appointment's foreign key is *RefIDAppointment*.

Table 4.7: Appointment table attributes

AppointmentDate	Appointment date between associated health professional and associated patient.

4.1.2 HIS Web Service

HIS is the central point of the system architecture. It communicates with HOPE-Wounds-Web application server and HOPE-Wounds mobile devices to retrieve and provide data. To perform these actions, it contains the database with all system information.

In order to exchange data with clients, HIS server uses web service technology. The following web methods are available to HIS clients:

- **requestLogin** - When a health professional logs in the system, this web method is used. User authenticates with its mechanographical number and password.
- **requestUnit** - This web method identifies the healthcare unit that target health professional belongs. Health professional mechanographical number must be provided.
- **requestPatientInfo** - This web method provides a single patient information. It occurs when a medical professional searches a patient by his or her SNS number.
- **requestPatientsByDay** - This web method provides target health professional's daily appointments for the specified date. It is useful for the mobile client, so health professional can instantly select a patient, avoiding a search by the SNS number.

- **requestPatientHistory** - This web method provides a list with the last ten patients that target health professional treated. It is useful for the mobile client, so health professional can instantly select a patient, avoiding a search by the SNS number.
- **requestpatientWounds** - This web method provides a list with all the wounds that target patient has in the server.
- **requestWoundEpisodes** - This web method provides the list of episodes of target wound. In other words, it sends all treatment information about the specified wound.
- **requestSingleEpisode** - This web method returns a single episode information. It is useful when a wound has many episodes. This would result in an overly large data transfer, because every episode has at least one associated image.
- **requestWoundDates** - This web method provides two dates. The date in which the target wound treatment begun, and the date of the last received treatment. This is very helpful when a patient has a large number of wounds, so health professionals can easily see which wounds are recent and which wounds are old.
- **createWound** - When a patient is evaluated for the first time, a target wound must be created.
- **sendAppointment** - When a health professional wants to insert in the system a new appointment, this web method is used. User must provide appointment date and target patient.
- **cancelAppointment** - When a health professional wants to cancel an existing appointment with a patient, this web method is used.
- **sendEpisode** - After collecting treatment information, mobile application uses this web service to insert episode information in the server. Target wound must be provided to the server.
- **updateEpisode** - When a health professional wants to edit an already inserted episode in the desktop client, this web method is used.
- **updateWoundStatus** - This web method defines a wound status. Wounds can be active or closed. Wounds are active while patient is receiving treatments. A wound is closed when patient does not need more treatments. Usually, this web method is used to define a wound status as closed. Target wound must be provided.

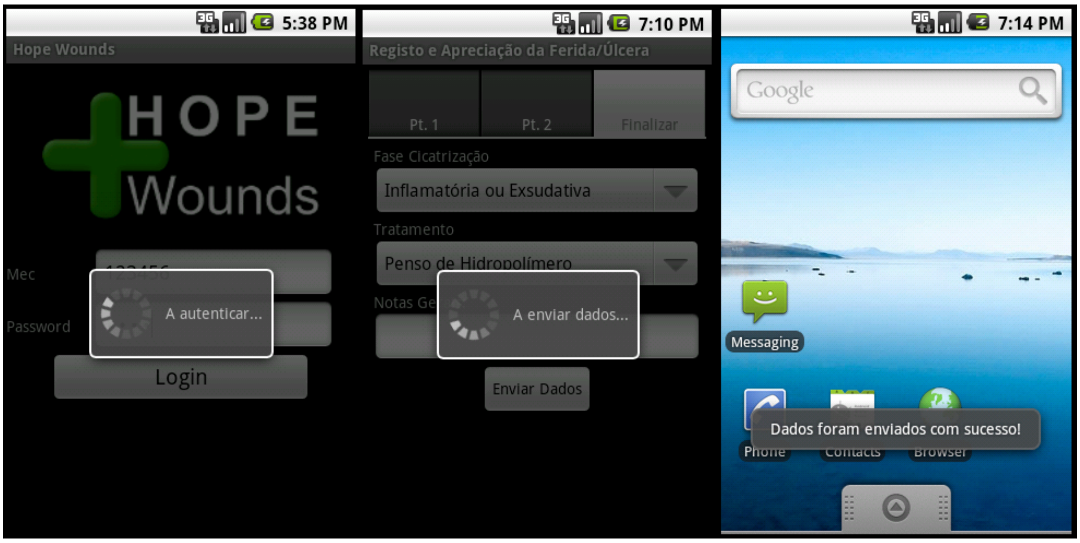
4.2 System Interactions Design

4.2.1 System Usability

In 1990, Jakob Nielson has established ten usability heuristics [30]. Since this application requires a lot of interaction from the user, system usability was a major concern in this project development.

The first heuristic rule ("Visibility of System Status - The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.") can be seen in long time operations.

When the user logs in the system, several web services are consumed, which takes some time to process, so, while HOPE-W waits for the response, the user is notified with the system status, as depicted in figure 4.3a. Another long time operation happens when user is sending the evaluation to the HIS server. As in the previous operation, the user has feedback while data is being sent to server (see figure 4.3b).



(a) Login feedback (b) Sending data feedback (c) Send data complete feedback

Figure 4.3: Nilsson's first heuristic rule examples

In both cases, system notifies the user when the operations are completed. In the last one, it is even possible to exit the application, and receive the notification as you were in the application (see figure 4.3c).

Heuristic **user control and freedom** is described as "Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo."

When user is defining wound measurement scale and drawing wound borders, there is a strong possibility of user mistakes. Drawings can be erased, allowing user to user to redo the drawings, as pictured in figure 4.4.

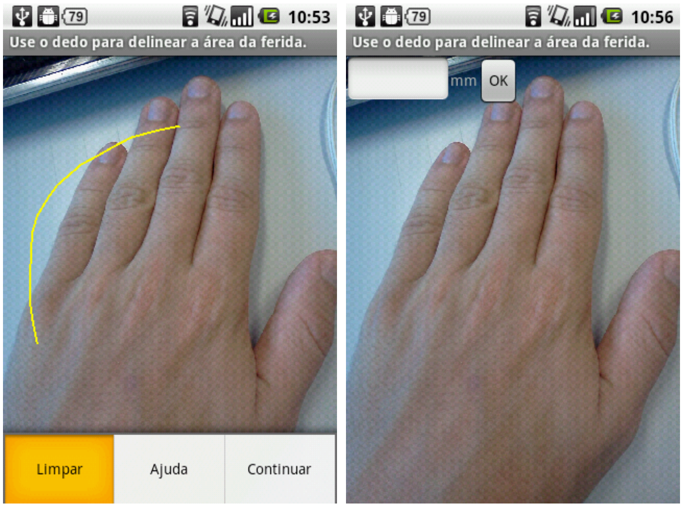


Figure 4.4: Nilsson's "user control and freedom" heuristic rule examples

Error prevention is described as "Even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action."

When user wants to commit an episode to the server, he has to confirm that action. Since the input in most part of the forms is facultative, this confirmation is essential to make sure that user has not pressed in "Send Data" button by mistake (see figure 4.5).

After capturing a picture of the wound, the scale is defined by the user through the choice of two reference points in the resulting image. The system then allows the input of the real distance between the selected points. Moreover, by denying the input of a single character, the system prevents that the user enters data in centimeters. This happens because requested measure is in millimeters and inputs with less than two characters would cause a larger precision error in the final results (see figure 4.5).

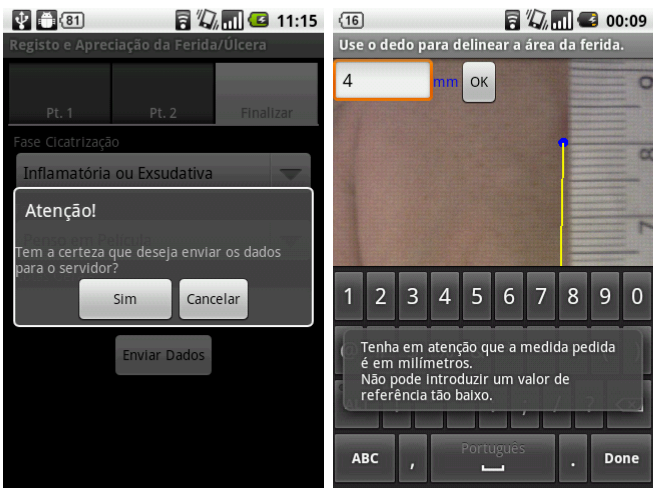


Figure 4.5: Nilsson's "error prevention" heuristic rule examples

Heuristic **Recognition rather than recall** ("Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.") is also taking into account in the system.

Patient unique identifier is their SNS number, a nine character length extension number. So, searching a patient requires a large input of data and a lot of interaction with the system. To avoid this, the system presents two lists containing the persons who most likely will be subject of an evaluation.

When a health professional logs in the system, a tab menu is displayed containing two lists: an agenda, listing patients that have an appointment in the current day with logged on health professional, and a personal history, listing the last ten patients that logged on health professional had treated, as pictured in figure 4.6.

Figure 4.6: Nilsson's "recognition rather then recall" heuristic rule examples

The last heuristic rule is **help and documentation** ("Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.").

Before complex operations, system provides helpful information so user can perform the desired task in a more accurate way. In example, HOPE-W explains which actions user will have to do to define wound perimeter, so system can calculate the wound total area (see figure 4.7).

Figure 4.7: Nilsson's "help and documentation" heuristic rule examples

4.2.2 HOPE-W Selected Features

Temporary Files

In case of network failure, it is impossible to send data to HIS server. So, the system creates temporary files to store episode information. The system is able to store any amount of evaluations in the SD card, and the only restriction is the capacity of the external card. When user logs in again, HOPE-W asks user if he wants to send the previous created files to the server. When the information is sent, temporary files are deleted.

Wound Area Measurement

After capturing the wound, user can define wound shape and system generates wound area. To perform this it is required that a reference point, such as a ruler, be captured along with the wound. User uses the reference object present in the image to define in which scale the image was taken. Then, user draws wound borders in the screen. The system automatically calculates wound height, wound width and wound area, based on these inputs.

Wound Measurement algorithms are explained in subchapter 5.2.1.

Agenda

To help health professionals selecting the target patient, there is an agenda in the system. It is possible to add appointments to the system, identifying in which day target patient will have the next treatment. With this feature, the list of patients for current day is presented to health professional after log in, avoiding a SNS number search by the health professional.

History

Besides the agenda, there is a patient history list in the system to help health professionals. Usually, wound treatments take several episodes, so it very likely that target patient will be evaluated again, or from other perspective, it is very likely that a health professional will handle target patient again in a short time. To avoid an overload of patients, this list is limited to the last ten patients that a health professional has handled.

Wound Location Selection

The system allows nearly thirty options to select the location of target wound, thus a human body image is presented so user can point the wound location. Body parts that are more likeable to suffer skin lesions were selected to compose the available selection.

Since the image is displayed in a small screen, a large number of options is displayed, and taking into account the human error when pressing a touch screen, the image was segmented, as it is shown in figure 4.8.

Each area contains several critic wound spots, so when user selects the location, possible wound locations that are included in the selected area are displayed. In example, if health professional selects the highlighted area, two options will appear, “left ear” and “right ear”.

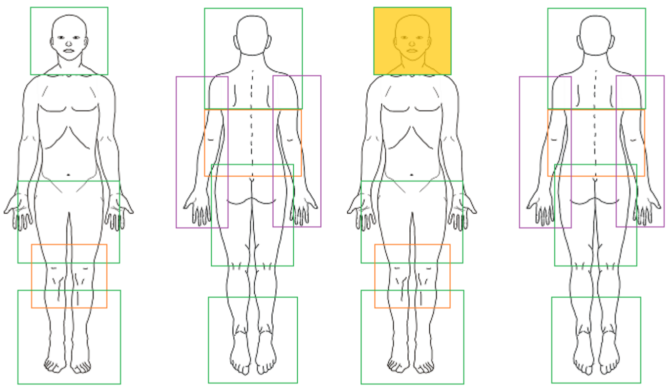


Figure 4.8: HOPE-Wounds Body Segmentation

System’s Information Distribution on the Screen

While developing for mobile device, some specific considerations have to be kept into account. Figuring out how to distribute system’s information on a small screen like mobile devices have is one of the greatest challenges in mobile development.

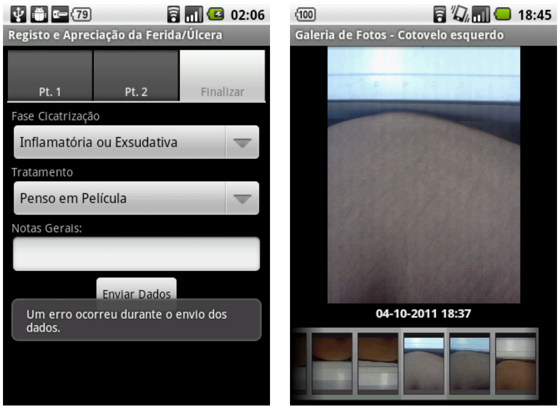
To avoid long pages, which would force users to long scrolls to access the bottom of the page or it could lead to forgetting to complete some system controls, tab pages are used. Thus, users can instantly see all information that is required by the system, and beyond, tabs can be very useful to arrange information, dividing user tasks in several steps.

Furthermore, to avoid an overload of information in the screen, Android hardware buttons are used. Otherwise, additional buttons would have to be present in the screen. BACK button is used to cancel actions or to go back in a workflow and MENU button is used to access additional information, perform system actions or to avoid the presence of buttons in the screen.

The use of tabs in the system can be seen when user fills wound related information forms, as pictured in figure 4.9a. The use of MENU button can be seen when user is defining wound boundaries (see figure 4.9b). Subsequently, user can observe the wound photo without additional controls interfering. Otherwise, there would be a risk of covering an important wound part.

(a) Wound data forms (b) Photo Gallery

Figure 4.9: Example of System's Information Distribution on the Screen



(a) Wound data forms (b) Photo Gallery

Figure 4.10: HOPE-W error prevention example and HOPE-W PhotoGallery

---

Text Inputs

One of the toughest and most inconvenient actions when using a mobile device, especially without hard keyboard, is text inputting. Regarding this, besides login, where the user has to write his or her credentials, the only required text box is when the user defines the scale of the picture. Due to the wide range of possible values, a numeric text box was the best solution.

Besides that, to minimize this problem, all measures in the system are requested in millimeters. As a consequence, inputs like "1.45", that require the use of non-numeric characters, are avoided.

External Errors Tolerance

As HOPE-Wounds requires communication with other systems, error prone situations increase: external system could not be capable of providing the expected result, or the wireless environment causes disconnection between the both parts. In these scenarios, HOPE-Wounds keeps the system integrity and warns the user of the current situation.

When data is not properly sent to HIS server, user is notified of the current circumstances, and system goes back to the previous state. User can try to send data again or to save it locally.

Figure 4.10a shows the system notification that is triggered when the system detects that data was not properly sent to HIS server.

Review of Wound Evolution

Patient Gallery gathers all information that was taken from a specific wound. Pictures are shown in a sequential line, in chronological order. Therefore, health professional can instantly see the wound progression, with quick access to every episode details.

Figure 4.10b shows system gallery. The list of small photos below represents all the photos that were taken to that specific wound. The large photo in the upper section represents the selected photo/evaluation that is selected in the moment.

Chapter 5

Implementation

5.1 Development Technologies

As this system is composed by several modules, several technologies are used. System architecture can be segmented in four different modules: Mobile application, web server application, HIS (Hospital Information System) and RTS services.
System architecture and used technology are described in figure 5.1.

As stated before, Android is the chosen mobile application operating system, and Java [31] was used as the programming language. Mobile application was developed in Eclipse IDE Helios Service Release 1. Android has an external library [1] to consume the SOAP web service that are provided by the HIS server.

Web server hosts the web page the professionals use to visualize data that is stored in HIS server database. This website was developed over .NET framework, and it is hosted in an IIS web server application. C# was used as the website programming language.

Hospital Information System is separated in two different applications: HIS Server and RTS Proxy Server.
HIS Server provides a set of web methods so clients can access data that is stored in the HIS database. This application was developed over .NET framework, C# was used as the main language and it is hosted in an IIS web server application. For development purposes, it was used Visual Studio 2008 Professional Edition Version 9.0 SP 1.
RTS Proxy Server consumes RTS web services, and provides redesigned web methods to be consumed by HIS Server application. Communication between RTS Proxy Server and RTS machine are secured. The encryption and authentication are done using X509 [2] certificates. This application was developed over Java platform, and it is hosted in an Apache Tomcat web server application. For development purposes, it was used NetBeans IDE 6.9.1.

The several existing applications in the system connect with each other using SOAP web-services technology. This communication method was maintained from the past projects. Messages are exchanged in XML format, and communication is established over HTTP, as it is pictured in figure 5.1.

All development was made in Microsoft Windows 7 Professional 6.1.7607 SP 1 (32 bits).

For development purposes, HIS Server and web server were deployed in a virtual machine within University of Aveiro *eduroam* network. It was only accessible from this network and

[1] `http://code.google.com/p/ksoap2-android/`
[2] `http://www.itu.int/rec/T-REC-X.509-200508-I/en`

it used Microsoft's IIS 7.0 web server. RTS Proxy Server was also hosted in a local machine within *eduroam* network.
LG-P500 was the primary smartphone used to test the mobile application. However, other devices were used to verify the compatibility among all android devices.

In Hospital Infante D.Pedro environment, the web server, HIS Server, HIS database and RTS Proxy Server were installed in the same physical machine.

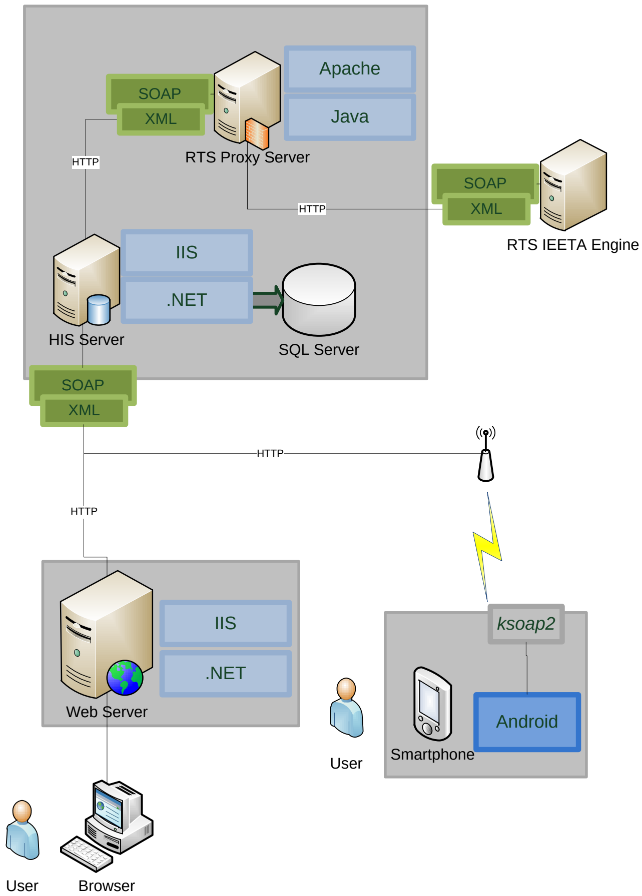


Figure 5.1: System Architecture

5.2 Android Platform

The mobile application was developed to run on any device with Android 2.1 (Eclair, API level 7) or superior. Hardware limitation is not a problem, since every smarthphone running Android available in the market fulfills this application's requirements:

- **Wireless access** - Wireless access is required to fetch patients' information and to authenticate health professionals.

- **Camera** - Camera is required to capture patients' wounds.

- **Flash** - Not required, but helpful. Especially when taking photos in poor illuminated environments. If there is not enough light is very likable that photos end up blurred. Enabling the smartphone flash will avoid this problem.

- **Memory card** - A memory card is required to store the pictures and the temporary files in case of network failure.

- **Touch screen** - Touch screen is required in several steps. For instance, wound shape definition, where health professional draws the wound perimeter over the picture with his or her finger.

Mobile application uses the *ksoap2-android-assembly-2.5.4-jar-with-dependencies.jar*[3] library to consume the SOAP web service that was made available by the HIS server.

XML technology is used to enable data persistence. When, for some reason, an episode cannot be sent to HIS server, episode information is stored locally. To perform this, a XML file is created and all episode information is stored in there.

After sending an episode to HIS server, a XML file is created and filled with episode information. This allows health professionals to consult patient evaluations in the own mobile device.

5.2.1 Wound Measurement

One of this system's main features is the capability to obtain and store wound shape and dimensions in the mobile device. To obtain this, it was developed an algorithm to ease user interaction diminishing complexity for the user.

A java class implementing View.OnTouchListener was used to define DrawAreaActivity layout (see figure 5.2).

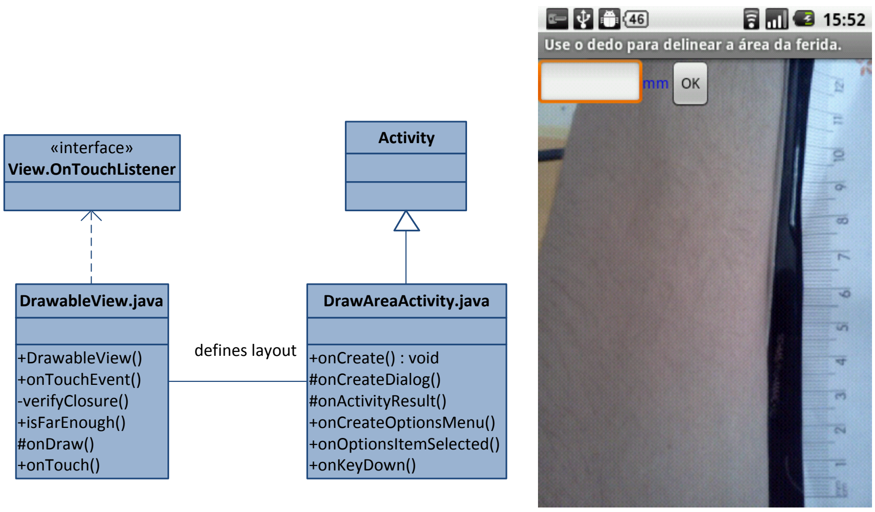


Figure 5.2: DrawAreaActivity.java class interactions and Activity layout

DrawableView uses event handlers to listen for user interactions. *onTouchEvent()* is triggered everytime a user interacts with the touch screen.

[3]http://code.google.com/p/ksoap2-android/

DrawableView actions can be organized in a workflow diagram.

In state 0, DrawableView is expecting a screen touch so it can draw the first reference point. When user touches and releases the finger from the screen, DrawableView moves to state 1. It is now expecting another screen touch from the user. When the user presses the screen, a new point is formed creating a connection with the first one. System current state is illustrated in figure 5.3).

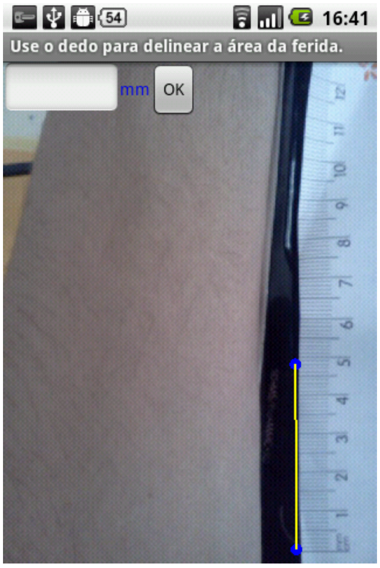


Figure 5.3: DrawableView status after user has defined the two reference points

System is now expecting that user introduces the distance between both reference points in the top *edittext* control. This value will define in which scale was the photo taken. After introducing the reference distance, system moves to state 2, and it is expecting a touch screen to identify the start point of wound boundaries.

The flowchart in figure 5.4 describes the algorithm behavior, from this state on.

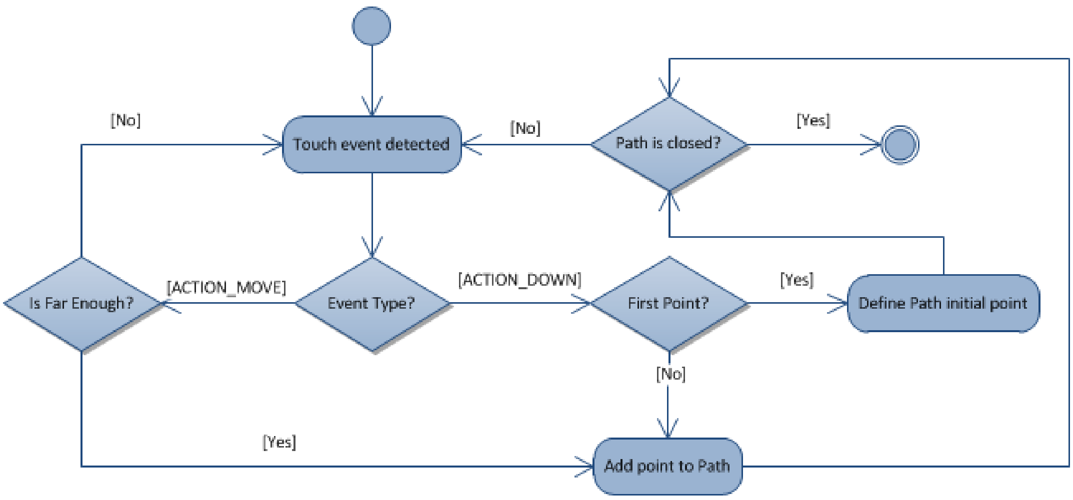


Figure 5.4: Drawing wound boundaries alghorithm flowchart

onTouchEvent is triggered anytime system detects movement in the touch screen. It identifies two different event types: ACTIONDOWN and ACTIONMOVE. The first one occurs anytime user presses the touch screen; the second one occurs when user is already touching the screen and moves the finger to a different position.

To store wound boundaries the class *MyPath* is used, which extends from the Android class Path (see figure 5.5). It is able to store several points, creating connections between them. There are two main methods to draw wound boundaries: *moveTo()* defines the current point of the path, and *lineTo()* draws a line between the current point and a point that is passed as a parameter.

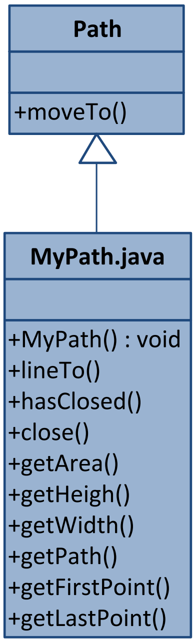


Figure 5.5: MyPath class

When user presses the screen, the system verifies if there are already inserted points. If it is the first screen touch, ACTIONDOWN event is detected and the first Path point is created. Then, application verifies if path is finished. To perform this, two aspects are evaluated: the number of points inserted in Path and the distance between the last point and the first point. So, two conditions must be valid to the wound be considered to be closed:

- Number of inserted points is greater than 3.
- First point is no closer than 10 pixels from the last point.

Giving these conditions, system will be now expecting another touch event.

When user presses in another location, onTouchEvent is triggered and ACTIONDOWN event is detected, and as Path already has inserted points, lineTo method will be used to draw a line between the last point and the point that user has just pressed. This sequence of events repeats until the inserted point is located near the first inserted point.

But user can also draw lines by sliding his or her finger on the screen. In this case, ACTIONMOVE event will be triggered. When this happens, system will verify to which position user moved. To avoid an overload of points just a few pixels apart, a new point will only be added if it is 10 pixels apart from the last point.

So, the user can draw wound boundaries using the most convenient method. He is able to draw straight lines or use the natural finger motion to draw the intended contour, as it is shown in figure 5.6.

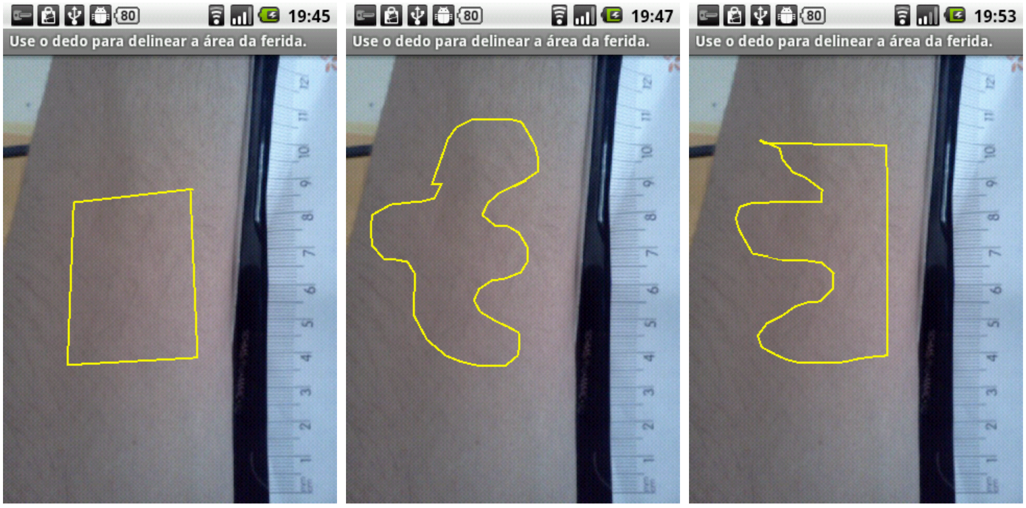


Figure 5.6: Wound boundaries drawings

The same algorithm is used to detect is a path is closed. Every time a point is added, system verifies if it is near the first inserted point.

When the drawing is completed, system automatically generates wound area, length and width. Wound width is calculated measuring the distance between the leftmost point and the rightmost point. Wound length is calculated measuring the distance between the topmost point and the bottommost point, as it is illustrated in figure 5.7.

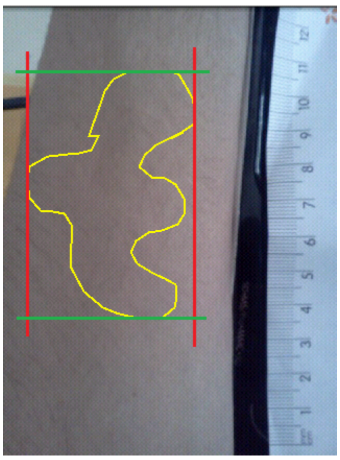


Figure 5.7: Imaginary lines that system uses to measure wound dimensions

Wound width is the distance between the two red lines, and wound length is the distance between the two green lines.

To obtain wound area, a polygon area algorithm is used (see figure 5.8). This is possible because wound borders are defined by a set of points, so it can be interpreted as a polygon.

```
// Public-domain function by Darel Rex Finley, 2006.
double polygonArea(double *X, double *Y, int points)  {
        double area=0. ;
        int i, j=points-1 ;
        for (i=0; i<points; i++) {
                area+=(X[j]+X[i])*(Y[j]-Y[i]); j=i;
        }

        return area*.5;
}
```

Figure 5.8: Algorithm used to calculate wound area [a]

[a] http://alienryderflex.com/polygon_area/

A tiny modification was added to this algorithm. In the original form, if polygon is traced counterclockwise, it returns a negative value for the area. So, it is returned the absolute value instead.

5.3 Android Activities

Android applications are segmented in activities. An activity is a fundamental part of the platform's application model, as activities are responsible for creating the user interface, so user can perform all kind of operations, as inputting text, view maps or taking photos. Activities can fill the screen or can host other activities.

An application can be described as a group of activities that interact with each other. The activity that is launched when the application starts is considered the "main" activity. Then, each activity can start another activity, as it is shown in figure 5.9. Each time a new activity starts, the previous activity is stopped, but the system preserves the activity in a stack, denominated as back stack [32]. If this new activity calls another activity, back stack will keep the two previous used activities. Otherwise, if the activity returns to the activity that has launched it (using the BACK key or the activity was launched expecting a response), the launched activity is popped from the stack and destroyed and the previous one is resumed and goes back to the top of the back stack, as shown in figure 5.9.

As previously stated before, activities are entities that communicate with each other. Activity's lifecycle callback methods are the mechanism that activities use to communicate. There are several callback methods that an activity might receive, depending in which state the activity is.

In example, when an activity is created, "onCreate()" is the correspondent callback method, when an activity gains focus, "onStop()" is called in the previous activity, when an activity is destroyed, "onDestroy()" is called. Activities are started from other activities, and in this call it is defined if parent activity is expecting a result. If so, it is possible to return values to the caller activity through a callback method.

Activities are also able to host other activities. Particularly, TabActivity can perform this action. TabActivity is an extension from ViewGroup that is extended from Activity.

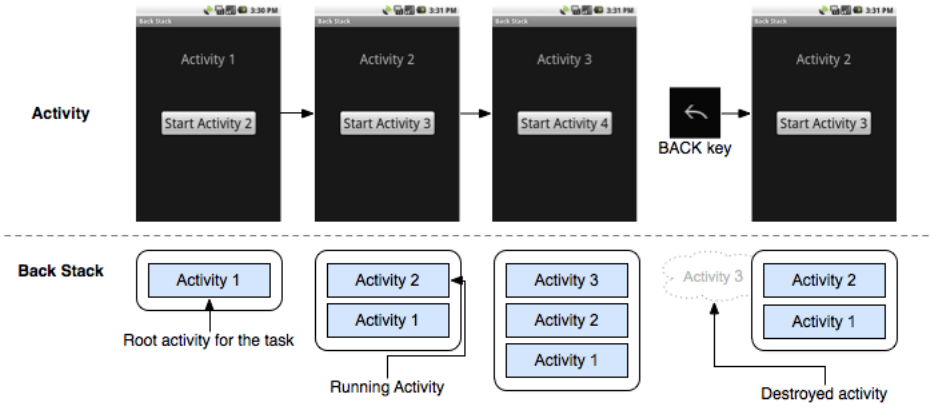


Figure 5.9: A representation of how each new activity in a task adds an item to the back stack. When the user presses the BACK key, the current activity is destroyed and the previous activity resumes. [32] [taken from `http://developer.android.com/guide/topics/fundamentals/tasks-and-back-stack.html`]

TabActivity displays hosted activities in a tabular layout and each tab hosts an independent activity.

The scheme in figure 5.10 describes the application architecture, with focus on system activities.

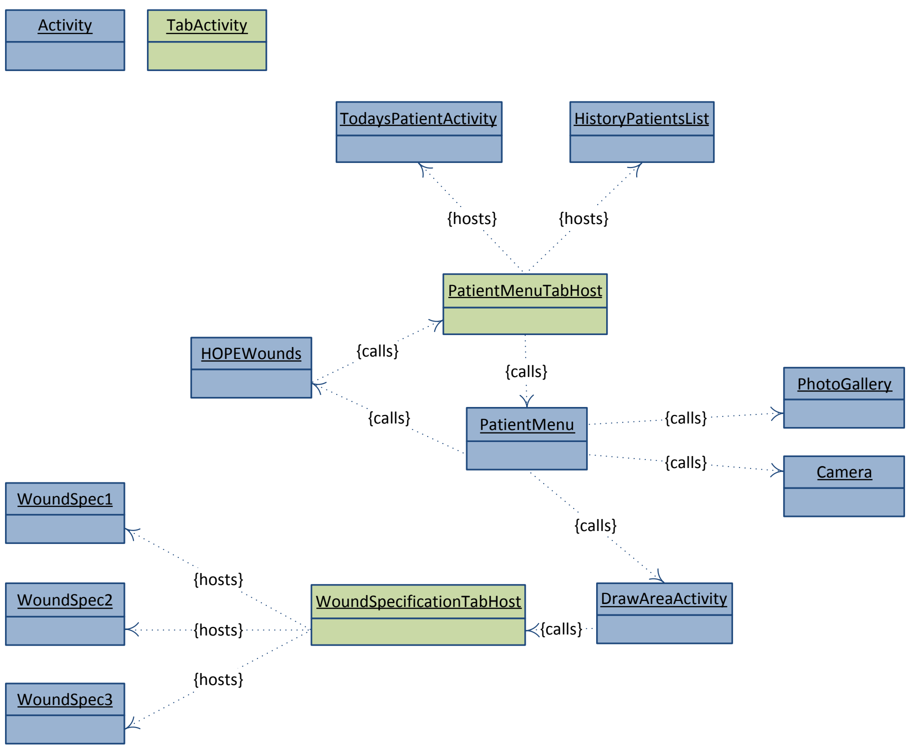


Figure 5.10: HOPE-Wounds Activities Class Diagram

Diagram in figure 5.10 represents all the system activities, and how they interact with each other. **HOPEWounds** (figure 5.11) is the main activity, which means that it is the activity that is launched when the application is started for the first time. This activity is responsible to authenticate the user in the HIS server. Also, it is responsible to send pending data to HIS when there are pending data files in the system. This activity calls **PatientMenuTabHost** Activity.

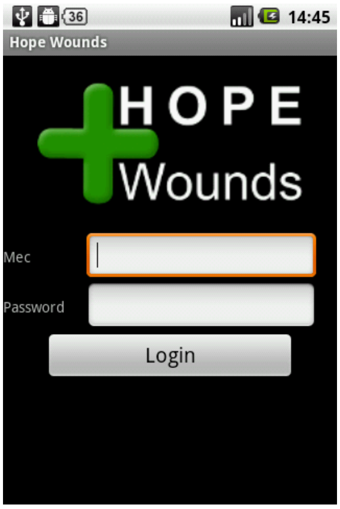


Figure 5.11: HOPEWound Activity

When PatientMenuTabHost activity (figure 5.12) is created it connects to HIS to get the history patients list and the list of patients that have an appointment scheduled for that day. To display the information that was retrieved, it hosts two activities:

- TodaysPatientList displays the list of patients that have an appointment in the system associated with logged on health professional in that day.

- HistoryPatientsList displays the recent history of patients that logged on health professional has treated. Also, a searchbox is displayed so users can search a patient by its SNS number. To perform this action, PatientMenuTabHost connects to HIS.

After selecting a patient, PatientMenu activity is launched.

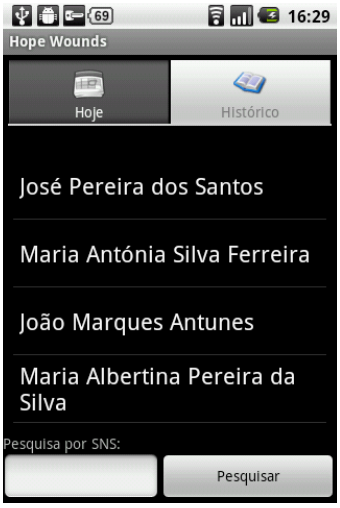


Figure 5.12: PatientMenuTabHost Activity

When PatientMenu activity is created (figure 5.13) it connects to HIS to retrieve the list of active wounds that selected patient have. PatientMenu can be considered the central activity of this application. This activity calls four other activities, as shown in figure 5.10. Patient information is displayed and active wounds are listed. Health professional can select which wound will be the target of the evaluation. Also, it is possible to insert new wounds on target patient records. Health professionals can start a new episode by taking a picture, or can see the previously inserted episodes by selecting the photo gallery.

If user wants to take a picture to insert a new episode, PatientMenu launches Android's native Camera activity, expecting the photo path as a response. After receiving Camera activity response, DrawAreaActivity is launched, so user can define wound perimeter. If user wants to see the past records of the selected patient, PhotoGallery activity is launched. If user wants to log out the system, HOPEWounds activity is called.

Figure 5.13: PatientMenu Activity

DrawAreaActivity user interface (see figure 5.14) is defined by a View that displays the picture that was taken in the previous activity as a background image. Additional controls were added so user could manually define the scale of the image.

In this activity health professional defines wound perimeter by drawing a line with the finger on the background image.

When user completes the drawing and accepts the final result, system calculates wound area, wound height and wound width. After that, WoundSpecificationTabHost activity is launched.

Figure 5.14: DrawAreaActivity

WoundSpecificationTabHost activity hosts three other activities: WoundSpec1, WoundSpec2 and WoundSpec3 (see figure 5.15). In these activities health professional fills the additional information about the wound status and describes which treatment was made.

WoundSpec1 shows wound length and wound width that was calculated in the previous activity. User is able to edit these values. Besides this, health professional can describe skin status in this section by filling a checkbox group. In WoundSpec2, user defines skin sensibility status, existing tissues and exudates status. In WoundSpec3, user specifies the wound healing phase, which treatment was made, and there is an additional field for additional information that the health professional considers to be important. After filling up the required information, it is possible to send data to HIS server or to save it locally in case of network failure. After completing this action, PatientMenu is launched again.

PhotoGallery activity (see figure 5.16) is responsible to show all information that was sent about the wound that was selected in the PatientMenu activity.

Figure 5.15: WoundSpecificationTabHost

Figure 5.16: PhotoGallery Activity

Images are displayed in a thumbnail list by chronological order, so user can easily navigate through the several records and instantly see the wound progression. When an image is selected, picture and episode date are displayed. User can see selected episode information by pressing the image; a dialog box appears displaying all information that was acquired when episode was inserted in the system. User can exit this activity by pressing the BACK button. PatientMenu activity is restored, and this activity destroyed.

5.4 Hope+

Prior to the HOPE-W system, another mobile system was developed. This mobile application had origin in HOPE+ [3]. As stated in the introduction, HOPE+ [3] is a mobile application designed to perform evaluations to patients. An evaluation can be performed once the patient enters the healthcare unit or it can be performed to update patient clinical record. Information regarding several clinical aspects, such as breathing, skin integrity images, circulation and body temperature is collected. After data being collected it was sent to a data server, just like HOPE-W system architecture.

The main goal was to restructure HOPE+ to match Hospital Infante D. Pedro requirements.

System's features and architecture were maintained. Main workflows had to be adjusted to the new healthcare environment, so most changes occurred in the system layout and input restrictions. Although, data structures in the mobile application and in the data server had to be adapted, to properly store the new required data.

Like HOPE-W, this application purpose was to insert clinical data in a data server. Thus, system architecture was similar, composed by a mobile application to gather clinical data, a web server to store the data and a web application to visualize it.

HOPE+ is also able to capture photographs. This way, health professionals are able to monitor wounds. Users are able to define wound contours in the website. When capturing wound photography, the same methodology is used: users have to include a reference object to define the scale afterwards.

HIP requirements implied that the system had to handle a larger amount of data. To avoid long scrolls and to kept system's previous workflow, tab controls were added to the system (see figure 5.17). Another important requirement was data validation, since there was a large number of controls in the system, it must be verified that users didn't skip any page or control by mistake. So, health professionals had to explicitly identify if a control was left unfilled intentionally (see figure 5.17).

System was developed in Windows Mobile 6.5.

Figure 5.17: HOPE+ new layout and input restrictions

Chapter 6

System Validation

6.1 Wound Measurement Test Results

To analyse the efficiency of the application, regarding wound measurement, user tests were performed.

Measurement tests were performed with objects and not real wounds so real area could be known. Using wounds, it would be impossible to know their exact area, because all measurement methods have precision errors.

Three different area values were used (see figure 6.1), matching figure 2.6 intervals of areas: 8 cm^2, 25 cm^2 and 50 cm^2. To simulate the wounds, geometric figures were used, so it would be possible to know the exact area value. Geometric figures were composed by rectangles and squares. Figures were twisted to force users to trace oblique lines.

Each object was measured five times. For each measurement, users had to define the scale of the photo. Before performing the tests, users experienced the system. After getting comfortable with the wound measurement tools, they started the test.

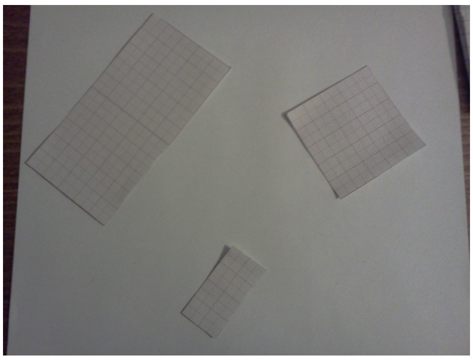


Figure 6.1: Area measurements target objects

Graph paper was used so estimated area could be the closest possible to the actual object area.

Analyzing table 6.1 results, and comparing with figure 2.6 results, it possible to say that the use of rulers still present the worst results.

This application's wound measuring method fits in the "digital photography" section. It presents slightly worst results than the ones presented in figure 2.6. However, it must be

Table 6.1: Test results for a 800mm^2 rectangle (40×20mm)

measure	obtained area (mm^2)	precision error (%)
1	705	11.875
2	779	2.625
3	706	11.75
4	735	8.125
5	840	5
average	**753**	**7,875**

taken into account that the results in figure 2.6 are based in measurements done in computer desktops, while table 6.1 measurements were obtained from a mobile device.

Table 6.2: Test results for a 2500mm^2 square (50×50mm)

measure	obtained area (mm^2)	precision error (%)
1	2464	1.44
2	2523	0.92
3	2625	5
4	2595	3.8
5	2624	4.96
average	**2566.2**	**3.22**

Table 6.3: Test results for a 5000mm^2 square (100×50mm)

measure	obtained area (mm^2)	precision error (%)
1	4928	1.44
2	4812	3.76
3	5075	1.5
4	4812	3.76
5	4816	3.68
average	**4888.6**	**2.828**

Table 6.2 presents considerably better results that the first one. It has a precision error of 3.22%, so it can be taken as an satisfactory result, when comparing with the values in figures 2.6 and 2.7.

Table 6.3 presents the lowest precision error values, when compared to tables 6.1 and 6.2. Like the results presented in figures2.6 and 2.7, the larger the area the lower the precision error.

When comparing with the values presented in figures 2.6 and 2.7, it is possible to say that the results are also satisfactory, presenting a precision error of only 2.8%.

Wound measurement test results are presented in figure 6.2. As stated, results are acceptable when comparing with other measurement tools.

HOPE-W also presents the same behaviour that others when object area is increased: Larger objects induce a minor precision error.

Since used objects were perfect squares or rectangles, making measurement an easier

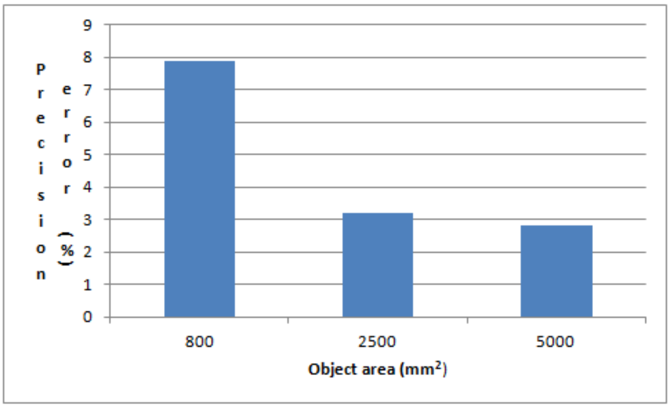


Figure 6.2: HOPE-W precision of measurement methods

process, objects with irregular shapes were also used to verify data consistency. These objects had the same area, but had different shapes, as it shown in figure 6.3.

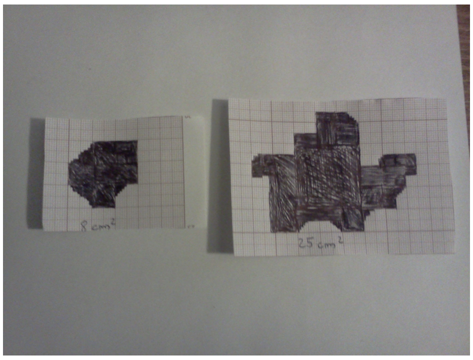


Figure 6.3: Area measurement target objects (second iteration)

Table 6.4: Test results for a $800mm^2$ irregular polygon

measure	obtained area (mm^2)	precision error (%)
1	816	2
2	934	16.75
3	742	7.25
4	785	1.875
5	906	13.25
average	**836.6**	**8.225**

When comparing table 6.4 with table 6.1, it is possible to say that results are similar. As expected, an irregular shape increases precision error, despite being a small difference.

Surprisingly, the 2500 mm^2 irregular polygon presents better results than the twisted square previously used. This can be explained by the fact that the test subject started getting used to the interaction, improving measuring values.

Once more, obtained values match the range of values of the other analysed studies, making this application obtained values acceptable.

Table 6.5: Test results for a 2500mm^2 irregular polygon

measure	obtained area (mm^2)	precision error (%)
1	2594	3.76
2	2561	2.44
3	2551	2.04
4	2498	0.08
5	2582	3.28
average	**2557.2**	**2.32**

Other variables, such as photo resolution and focal distance, are not mentioned here, because it was concluded that this variables did not take significant relevance in the obtained results. Although, it is recommended that the focal distance be the shortest as possible, for a greater wound definition in the photography.

Another round of tests was conducted using objects with elliptic shapes. This time, in addition to area, wound width and height precision are also evaluated.

So far, presented results were obtained by test subjects that had previous training. This is, they experienced the application before submitting to tests. Table 6.6 test experience was performed by inexperienced users, this is, it was the first time they were using this application.

Table 6.6: Test results for a 4×2cm ellipse (area = 2513mm^2)

measure	**area** (mm^2)	**p. error** (%)	**width** (mm)	**p. error** (%)	**height** (mm)	**p. error** (%)
1	2580	2,67	41	2,5	80	0
2	2696	7,28	40	0	79	1,25
3	2542	1,15	39	2,5	84	5
4	2883	14,72	44	10	80	0
5	2701	7,48	41	2,5	82	2,5
6	2396	4,66	41	2,5	75	6,25
7	2340	6,88	39	2,5	73	8,75
8	2699	7,40	41	2,5	76	5
9	2371	5,65	38	5	74	7,5
10	2733	8,75	40	0	80	0
11	2498	0,60	41	2,5	76	5
12	2498	0,60	40	0	75	6,25
13	2459	2,15	41	2,5	72	10
14	2571	2,31	41	2,5	74	7,5
average	**2569,07**	**5,16**	**40,5**	**2,67**	**77,14**	**4,64**
[1-10]	2594,1	6,67	40,4	3	78,3	3,625
[11-14]	2506,5	1,41	40,75	1,875	74,25	7,1875

Regarding wound area measurements, a precision error of 5.16% was obtained. Precision errors of 2.67% and 4.64% were obtained when measuring wound height and width.

Comparing table 6.6 average results with previous results, it can be concluded that table 6.6 presents the worst results. Still, it presents better results when compared with the average precision error induced by rulers (figure 2.6), and values are within the expected when compared with other digital photography methods, as pictured in figure 2.6.

In addition to the obtained mean of all measurements and respective precision errors, in the bottom of table 6.6 are presented results taking into account user experience. Results obtained by the last four obtained records are significantly better than the previous ones. Precision error of area measurements decreased from 6.7% to 1.41%. Precision error of wound width also decreased from 2.67% to 1.88%. Precision error of wound height presented unexpected results. Contrary to the precision error of wound area and width, obtained results were actually worse. Precision errors arise from 3.63% to 7.19%.

Results prove that user experience is very important when measuring wounds with this application. The more times a user performs wound measurements, best results will be obtained, so wound measurement results are improved over time. As a result, HOPE-W is an application that has a learning curve, and health professionals should test it before using it in the field.

The improvement of measurement values over time could also means that users became accustomed to the wound shape, so the same test will be repeated, but the object will have a different shape. Next test will be performed to evaluate that there is actually a learning curve. Users that experienced for the first time the application (table 6.6) will now repeat the experience with an object that has the same area, but a different shape. Smoother results will be expected.

Table 6.7: Test results for a circle (area = 2513mm^2, r=56mm)

measurement	**area** (mm^2)	**p. error** (%)	**width** (mm)	**p. error** (%)	**height** (mm)	**p. error** (%)
1	2431	3,26	56	0,00	54	3,57
2	2603	3,58	54	3,57	56	0,00
3	2418	3,78	55	1,79	53	5,36
4	2500	0,52	55	7,14	55	1,79
5	2721	8,28	53	5,36	60	7,14
6	2398	4,58	53	8,93	54	3,57
7	2514	0,04	53	5,36	56	0,00
8	2531	0,72	56	0,00	57	1,79
9	2789	10,98	56	0,00	59	5,36
10	2397	4,62	53	8,93	55	1,79
average	**2530,2**	**4,04**	**54,4**	**2,86**	**55,9**	**3,04**

Table 6.7 presents better results, when compared to table 6.6. Comparing the first ten measurements of both tables, area precision error decreased from 6.7% to 4.0%. Width and height precision errors have slightly decreased.

However, the last four results from table 6.6 present better results than table 6.7, with the exception of height precision error. This exception can be explained because width and height obtained values are much lower than the values obtained in area measurements, as a result precision error are much more unstable, just like smaller areas present higher precision error values. Area measurement values are not affected because area is not calculated based on these values, as explained in the previous chapter.

Table 6.7 presents better results than table 6.6. Since it was the same users performing the measurements, this behavior can be justified by the possibility that users have improved their measurement skills. The last four results of table 6.7 are even better than table 6.6. This behavior can be explained by the possibility that users have accustomed to the object shape, improving results.

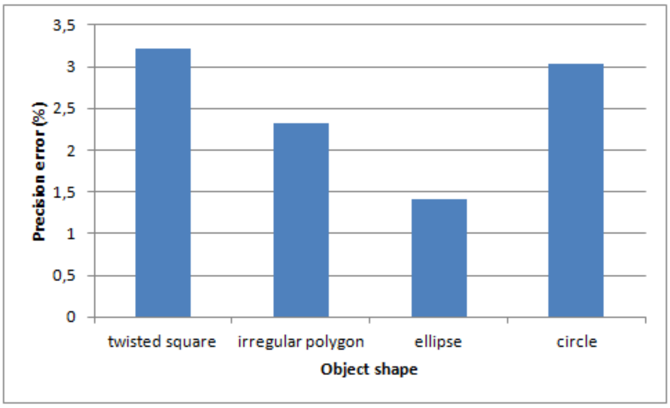


Figure 6.4: HOPE-W average precision error of measured objects

Figure 6.4 presents wound measurements precision errors based in the different used objects. For each object, four different test subjects were used. Users were not used to lead with smartphones in a daily basis. The square and the polygon area were 2500 mm^2, while the ellipse and the circle area were 2513 mm^2. It can be concluded that, no matter the target object is, results are always satisfactory. The square object presents the least satisfactory results, however, precision error does not even reaches 3,5%.

6.2 User Testing Results

To evaluate HOPE-W acceptance in clinical use, it were realized user tests in Hospital Infante D.Pedro. Nursing staff were the target users, as nurses will be the main users of this system, since they are responsible for performing the wound treatments.

The testing group consisted of sixteen nurses. Fourteen users were female (87,5%), against only two male users. Test subjects age distribution is illustrated in figure 6.5.

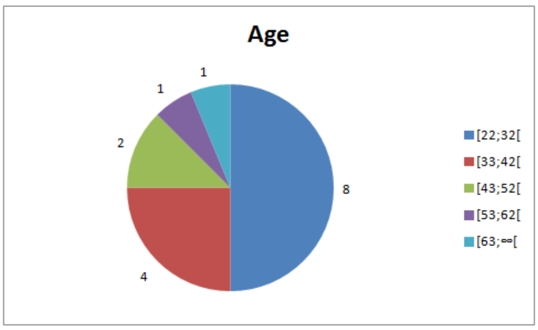


Figure 6.5: Age distribution of test subjects

Users had to answer a form in which they were asked to perform a series of actions. User forms can be seen in appendix A. While performing tasks, they were being monitored by an observer that had to fill a specific form (see appendix B). Nine tasks were selected to be part of this test:

- **1 - Login:** This is always the system's first task. User has to input the given credentials and check if authentication is correct.
- **2 - Search patient:** This task forces the user to input a number in the textbox and search the inserted number.
- **3 - Add Wound:** In this task, user has to add a specific wound to the previous selected patient. Wound localization is indicated in the user task form.
- **4 - Take Photograph:** In this task, user has to select the recently created wound and take a picture.
- **5 - Perform measurements:** In this task, users have to define wound boundaries.
- **6 - Fill additional forms:** In this task, users have to insert wound related information in the system. Information was provided in the user tasks form.
- **7 - Check previous photo:** In this task, users have to visualize the photo that was previously taken.
- **8 - Logout:** In this task, users have to terminate the current session.
- **9 - Login & Select Patient:** Since requested patient is the same that in task 2, users can select desired patient in the history tab. This task will evaluate how test subject had proceeded.

While performing tests, users identified the difficulty of the task on a scale from 1 to 5. Results can be seen in appendix C and in figure 6.6.

Almost all users experienced few difficulties to accomplish the proposed tasks. As expected, the task that users had more difficulties to accomplish was task number 5: performing measurements. Even so, only one of the sixteen users classified this task as somehow difficult, while the majority classified this task as "neither easy nor difficult".

Regarding task number 3, most test subjects classified this task as "neither easy nor difficult". Users also identified that the "Add Wound" button was hardly visible, so this result can be justified by this aspect. Remaining users identified this task as "easy".

As expected, task number 9 presents better results when compared with task 1 and 2. This occurs because when user is performing the last task, the patient that was selected in task number 2 appears in the history list, so user does not have to search again the requested patient.

The amount of time spent by each user was measured while he or she was performing the requested tasks. Results are displayed in figure 6.7. It was established a maximum value for each task. If test subject exceeded the maximum time, the task will be marked as incomplete. Everyone has completed the proposed tasks in the desired time.

As expected, the task that required more time to complete was wound measurement. Followed by task number 6, in which users had to fill three pages with wound related information.

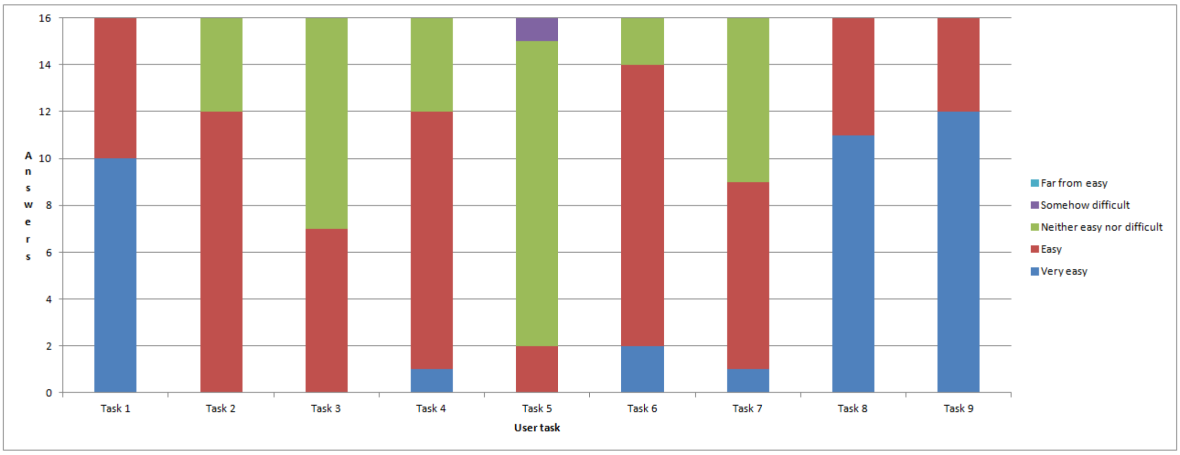


Figure 6.6: Difficulty of each user task

This is also an expectable result, since these are the tasks that require more interaction with the system.

The task that took less time was task number 8. In this task, users had to logout the system. This is performed by pressing the MENU button and then "logout" button, being the task that required the least interaction with the system.

All other results are acceptable.

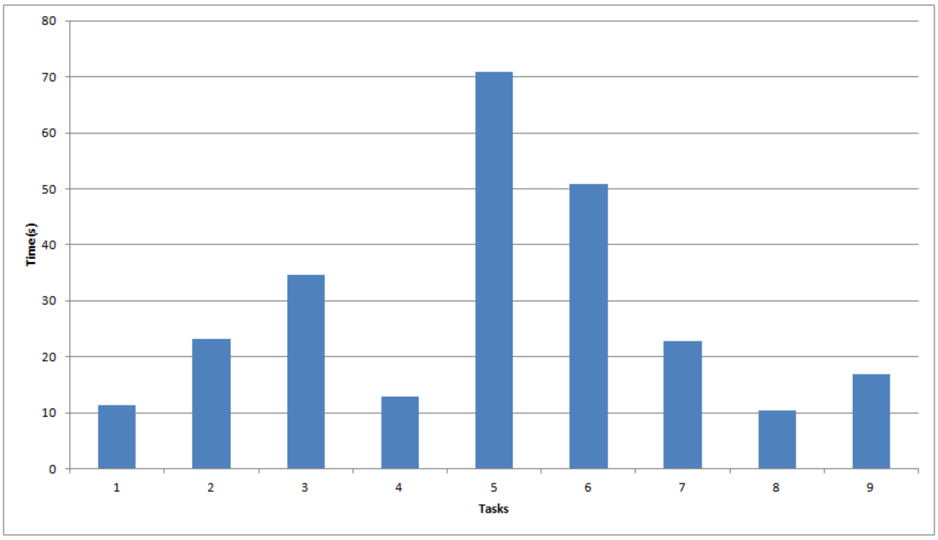


Figure 6.7: Average time spent by users in each task

After completing all tasks, users answered some questions about their experience using the system. Results can be consulted in appendix C.

Only one of the surveyed did not agreed that the system was easy to follow. Also, only one person did not agreed that they could easily find what they were looking for in the system. All test subjects agreed that the system was not slow.

When test subjects were questioned if the system was pleasant to use, almost everyone answered positively, fifteen persons agreed and only one person did not agree nor disagreed.

Nobody disagreed. Also, everyone agreed that data is properly distributed in the system.

The most surprising result is when users were questioned if they required help in some system features. Only three respondents answered affirmatively and half the users disagreed. Although, when enquired if users should have experience or greater knowledge using the system, five of the sixteen test subjects agreed.

Taking all this results into account, it is possible to declare that results are pretty satisfactory. Although, a large number of test subjects identified annoying aspects in the system, so it is very important to evaluate these answers and improve the system.

One last form was filled in to evaluate how information was distributed in the mobile application. (see appendix C, page 3)

Only one of the test subjects complained about characters size for being too small to read. Twelve participants were satisfied with their size.

All test subjects agreed that the most important information is properly highlighted.

Regarding HOPE-W design, twelve of the inquired agreed that the system was attractive, while the remaining test subjects did not agree nor disagree. Besides that, thirteen of the inquired agreed that the icons used in the application are intuitive. The remaining test subjects didn't agree nor disagree.

When questioned if the information was properly distributed in each page, thirteen of the users answered positively. The other ones neither agree nor disagree. Similar results are obtained when questioned about the amount of information in each page. This time, fifteen of the sixteen respondents answered affirmatively. Once more, the remaining one neither agree nor disagree.

Finally, thirteen of the test subjects agree that the mobile system has an easy navigation. The other three test subjects neither agree nor disagree.

From the obtained results, it is possible to declare that information is properly distributed in the system, and that users find the system easy to use.

Chapter 7

Conclusions

A main conclusion to be taken is that this application is able to properly collect and store wound related information. Application is also capable of retrieving wound dimensions, with acceptable precision error values, proven by the results. And more, HOPE-W wound measuring results show better precision error values that the achieved values when measuring with rulers, as it the case of Hospital Infante D.Pedro. However, this application has a learning curve. The more times a user uses the wound measurement feature, the best results will obtain.

System's workflow is adequate and intuitive for the healthcare environment. This statement is supported by the usability test results that were performed in Hospital Infante D.Pedro. Usability tests were performed by the health professionals of Hospital Infante D. Pedro, and obtained results are quite satisfactory. Most users found the system easy and pleasant to use.

System was also successfully integrated in RTS network. System is ready to be used by any health professional registered in the RTS. As well, obviously, all patients that are inserted in RTS can be used in this system.

Also, system was successfully integrated with HOPE-W website, which did not belong to this dissertation scope, being subject of another dissertation. Due to this integration, health professionals are now able to collect patient wound related information, and to store it in HIS server, making it accessible to any health professional that is inserted in the RTS network. HOPE-W website can properly receive all inserted information, so health professionals are able to analyse all past evaluations that were submitted. Therefore, these system's integration allow health professionals to remotely monitor wounded patients.

HIS server database design proved to be a good approach. Both clients, HOPE-W mobile applications and HOPE-W website, require HIS services, and HIS server is capable of storing and provide all the required information that both clients need.

Regarding the aspects mentioned before, it is possible to declare that mobile devices can be a useful tool in the healthcare environment. The use of their integrated cameras and connectivity to wireless networks enables mobility and flexibility in health professionals routines, as paperwork is reduced.

7.1 Work Summary

HOPE+ [3] is a mobile application that was developed to support the evaluation registry of nursing patients. This application served as a starting point to create a specific nursing evaluation registry application, oriented to Hospital Infante D.Pedro requirements.

To accomplish this, evaluation registry paperwork of nursing patients was analyzed, so the mobile application could retrieve the same information that nurses already retrieved. As HOPE+ was already designed for collecting evaluation registry data, the main changes that were made in the application were the application forms, and consequently, the required data. Since HOPE+ was developed in Window Mobile 6.5, and most required changes were layout aspects, system architecture was maintained, so the framework was kept.

HOPE+ was supported by an HIS server, which collected the information that was gathered by the mobile application. HIS server was maintained, but changes were made in data structured in order to support the new data that was required by HIP.

But the main goals of this dissertation was to create a mobile application that were capable to help health professionals when treating skin wounded patients, such as diabetic foot and pressure ulcers. This applications was named "HOPE-W".

A new android application was designed and developed to support those requirements. Unlike the previous one, this application was created from scratch. HOPE-W is able to be used by any health professional inserted in the RTS. Health professionals can use the mobile device application to describe the applied treatment and collect wound informations, such as the healing phase or the applied treatment. Also, health professionals are able to measure wound dimensions and to define the wound boundaries in the own device.

Like HOPE+, HOPE-W uses a server - HIS server - to store all acquired information. This server was developed in the same framework that the previous one, and web service technology was used to enable communication with clients. Web methods were defined and implemented to response to HOPE-W and HOPE-W website needs. A SQL database was designed and implemented, taking into account that it has to support all information that was collected by the mobile application.

7.2 Future Work

Several aspects can be pointed towards future work. User tests provided an excellent feedback to identify which aspects can be improved in HOPE-W mobile application. Several aspects were pointed. The most important ones were from a layout basis, like button appearances or the color of some controls. One of this applications core tasks - wound measurement feature - can be improved too, so users make fewer mistakes when defining the scale and defining wound limits. Despite of the acceptable precision errors, user experience could be improved. Currently, the line is traced in the exact point that user pressed. It would be quite interesting to evaluate the system performance if an image recognition algorithm was added to the system. When defining a point, system could search the surrounding area for the exact point where the boundary is located, although some wounds have imprecise boundaries.

HIS Server keeps the records of every episode that is inserted through the mobile application. Each episode is related to a single wound, and that wound location is stored in the server. In this system, human body is segmented in critical areas that are more probable to suffer wound lesions. So, it would be interesting to produce a statistics page about the data that is inserted in the server, such as the body areas that are more likeable to have skin wounds and the average time a full treatment takes to be completed.

HIS server and the existing health network allows the exchange of information between different healthcare units, so it can support other mobile applications. This mobile application is focused on wound image retrieval and analyses. Other mobile applications can be implemented focused in other tasks, like automedication applications.

Nowadays, almost every smartphone is equipped with capacity screens, which means that users use their finger to interact with the screen, instead of a stylus. However, there are styluses especially conceived for this kind of screens. When users are drawing the wound limits, they cannot see the point that is being drawn. This was one of the major difficulties that users had when using the system. It would be interesting to evaluate if a stylus would improve the drawing precision when the user is defining the wound boundaries.

Patient's and health professional's information are present in the RTS. After receiving the data, HIS server stores it in the local database to avoid further connections. At the present time, if RTS patient information is updated in the RTS, HIS server will not took acknowledgment of it, keeping the initial information. A synchronization mechanism between both databases could be added to ensure that all information is updated.

Also, communication between HOPE-W mobile application and HIS server is not secured. Ensuring secure communications would mean a major improvement in this system. This is very important because the communication is done over a wireless network.

User tests were performed to evaluate the precision error of HOPE-W wound measuring results. It is possible to draw some conclusions, which are described in the previous sections. However, the amount of performed tests is not sufficient to draw strong conclusions, so we should not put away the possibility to perform additional tests to ensure the reliability of the system.

References

[1] Thematic Network (Working Group) "Information Society for All" Constantine Stephanidis. *Universal access in health telematics: a design code of practice.* 2005.

[2] João Filipe Costa Ribeiro. Hope - cuidados de enfermagem apoiados em computação móvel. Master's thesis, Universidade de Aveiro, 2008.

[3] Ivo da Veiga. Hope+: Dispositivos móveis na avaliação de doentes em enfermagem. Master's thesis, Universidade de Aveiro, 2008.

[4] S. Chong-de. Experience and application of the mobile nursing technology [j]. *Lishizhen Medicine and Materia Medica Research*, 11, 2007.

[5] R.S.H. Istepanian and C.S. Pattichis. *M-health: Emerging mobile health systems.* Springer-Verlag New York Inc, 2006.

[6] João P.S. Cunha Ilídio C. Oliveira. Integration services to enable regional shared electronic health records. *Studies in Health Technology and Informatics*, 169:310 – 314, 2011.

[7] Rts - rede telemática da saúde. `http://www.rtsaude.pt`, Oct 2011.

[8] Dr. T.C.Manjunath Reema Sharma. Development of a conceptual view of a patron queuing system in tcp / ips. *International Journal of Computer Applications*, 8:35–39, 2010.

[9] Massimo Ancona Gianluca Quercini. Text entry in pdas with wtx. *The Ergonomics Open Journal*, 2:185–195, 2009.

[10] K. Tomas, M. Filip, and S. Antonin. Mobile approach, trends, and technologies in modern information systems. In *7th WSEAS International Conference on Applied Computer and Applied Computational Science*, pages 6–8.

[11] S. Berger, S. McFaddin, C. Narayanaswami, and M. Raghunath. Web services on mobile devices-implementation and experience. In *Mobile Computing Systems and Applications, 2003. Proceedings. Fifth IEEE Workshop on*, pages 100–109. IEEE, 2003.

[12] Gartner. Worlwide sales of mobile devices in second quarter of 2011. http://www.gartner.com/it/page.jsp?id=1764714, August 2011.

[13] Marsha J. Handel. mHealth (Mobile Health)-Using apps for health and wellness. *Explore - The Journal of Science and healing*, 7(4):256–261, JUL-AUG 2011.

[14] C. Davenport. Analysis of pdas in nursing: Benefits and barriers. *PDA Cortex*, 2004.

[15] R. Martin. Making a case for personal digital assistant (pda) use in baccalaureate nursing education. *Online Journal of Nursing Informatics (OJNI)*, 2007.

[16] S.L. De Groote and M. Doranski. The use of personal digital assistants in the health sciences: results of a survey. *Journal of the Medical Library Association*, 92(3):341, 2004.

[17] CMSRN CRNP ANP-BC Karen Innocent MS, RN. Tech talk: Mobile apps for nurses. *Nursing2011 Critical Care*, 5(5):45 – 47, September 2011.

[18] P. Sheehan, P. Jones, A. Caselli, J.M. Giurini, and A. Veves. Percent change in wound area of diabetic foot ulcers over a 4-week period is a robust predictor of complete healing in a 12-week prospective trial. *Diabetes Care*, 26(6):1879, 2003.

[19] A.M. Fette. A clinimetric analysis of wound measurement tools. *World Wide Wounds. January*, 2006.

[20] D. Langemo, J. Anderson, D. Hanson, S. Hunter, and P. Thompson. Measuring wound length, width, and area: which technique? *Advances in skin & wound care*, 21(1):42, 2008.

[21] D.K. Langemo, H. Melland, D. Hanson, B. Olson, S. Hunter, and S.J. Henly. Two-dimensional wound measurement: comparison of 4 techniques. *Advances in Skin & Wound Care*, 11(7):337, 1998.

[22] H.A. Thawer, P.E. Houghton, M.G. Woodbury, D. Keast, and K. Campbell. Computer-assisted and manual wound size measurement. *Ostomy/wound management*, 48(10):46–53, 2002.

[23] J. McCardle. Visitrak: wound measurement as an aid to making treatment decisions. *Diabetic Foot*, 8(4):207, 2005.

[24] A.C. Chang, B. Dearman, and J.E. Greenwood. A comparison of wound area measurement techniques: Visitrak versus photography. *Eplasty*, 11, 2011.

[25] P. Plassmann and TD Jones. Mavis: a non-invasive instrument to measure area and volume of wounds. *Medical engineering & physics*, 20(5):332–338, 1998.

[26] JI Kundin. Designing and developing a new measuring instrument. *Perioperative nursing quarterly*, 1(4):40, 1985.

[27] D.C. Kieser and C. Hammond. Leading wound care technology: The aranz medical silhouette. *Advances in Skin & Wound Care*, 24(2):68, 2011.

[28] M. Romanelli, V. Dini, L.C. Rogers, C. Hammond, and M. Nixon. Clinical evaluation of a wound measurement and documentation system. *Wounds*, 20(9):256–264, 2008.

[29] P. Plassmann, C. D. Jones, and M. McCarthy. Accuracy and precision of the MAVIS-II wound measurement device. *Wound Repair and Regeneration*, 15(6):A129, NOV-DEC 2007.

[30] J. Nielsen. Heuristic evaluation. in nielsen, j., and mack, r.l. (eds.). *Usability Inspection Methods, John Wiley & Sons, New York, NY.*, 1994.

[31] J. Bloch. *Effective Java.* Prentice Hall, 2008.

[32] Android developers. `http://developer.android.com`, June 2011.

Appendix A

User Test Form

Tarefas do HOPE Wounds Mobile
HOPE Wounds Mobile Tasks

Tarefa 1 **Task 1**	Efectue o registo no sistema, para tal pode utilizar as seguintes credenciais: Log on the system. The following credentials should be used: Mec: *M1HIP*, Pass: *123*: -- Nada Fácil / Far from easy 1 2 3 4 5 Muito Fácil / Very easy
Tarefa 2 **Task 2**	O SNS é o idenficador único utilizado para distinguir pacientes. Encontre o paciente com o SNS “123456789”. SNS is used as the unique identifier to differentiate patients. Find the patient which SNS number is “123456789”. **Nome do paciente / Patient name:** **O paciente tem feridas activas?** Sim/Não **Patient has active wounds?** Yes/No -- Nada Fácil / Far from easy 1 2 3 4 5 Muito Fácil / Very easy
Tarefa 3 **Task 3**	Com o paciente seleccionado, adicione uma nova ferida ao sistema, localizada no tornozelo esquerdo. With the patient that was selected, add a new wound to the system. -- Nada Fácil / Far from easy 1 2 3 4 5 Muito Fácil / Very easy
Tarefa 4 **Task 4**	Tire uma fotografia à ferida em questão, e grave-a no dispositivo. Take a picture to the wound in question, and save it in the device. *É necessário a fotografia incluir um objecto de medição (como um régua) de modo a ser possível definir a escala da foto posteriormente.* *Photograph must include a measurement object (like a ruler) in order to set the scale of the photo later.* -- Nada Fácil / Far from easy 1 2 3 4 5 Muito Fácil / Very easy
Tarefa 5 **Task 5**	Seguindo as instruções apresentadas no dispositivo, defina a escala na qual a fotografia foi tirada, e a forma da ferida em questão. Avance para a fase seguinte, quando completar a tarefa. Following the instructions on the device, set the scale on which the photograph was taken, and define the wound shape. Move on to the next phase, after finishing the task. -- Nada Fácil / Far from easy 1 2 3 4 5 Muito Fácil / Very easy

Figure A.1: User Test Form - Page 1

Tarefa 6 **Task 6**	A ferida apresenta as seguintes características: The wound has the following properties: • A pele circundante apresenta-se seca. • Surrounding skin has dried up • Sensibilidade suportável. • Bearable sensitivity • Tecidos presentes são irrelevantes. • Existing tissues are irrelevant • Quantidade de exsudado é reduzida e existe cheiro. É do tipo seroso. • Reduced amount of exudate and there is smell. It is serous type. • A ferida encontra-se na fase de maturação e o tratamento aplicado foi GG + Betadine. • Wound is on maturity and applied treatment was GG + Betadine. Tendo em conta os dados fornecidos, preencha o formulário da aplicação, e envie os dados para o servidor. Given the provided data, fill the application forms and send the data to the server. --- Nada Fácil / Far from easy [1][2][3][4][5] Muito Fácil / Very easy

Tarefa 7 **Task 8**	Visualize a foto que enviou nas tarefas anteriores. Visualize the photo you sent in the previous tasks. --- Nada Fácil / Far from easy [1][2][3][4][5] Muito Fácil / Very easy

Tarefa 8 **Task 8**	Termine a sessão. Log out the system. --- Nada Fácil / Far from easy [1][2][3][4][5] Muito Fácil / Very easy

Tarefa 9 **Task 9**	Volte a fazer login no sistema, e seleccione de novo o paciente ao qual fez a avaliação anterior. Re-login the system and select again the patient to whom you did the previous evaluation. --- Nada Fácil / Far from easy [1][2][3][4][5] Muito Fácil / Very easy

Figure A.2: User Test Form - Page 2

Appendix B

Observer Guide Form

Nº de utilizador: ____________

Guião do Observador do módulo HOPE Wounds Mobile

Tarefa	Tarefa	Completou a Tarefa?	Tempo Máximo / Tempo observado (mm:ss)	Cometeu erros?	Sentiu-se perdido?	Solicitou ajuda	Grau de facilidade observada 1 – Nada Fácil 5 – Muito Fácil
1	Autenticar-se	não __ sim __	30 s ____	não __ poucos __ muitos __	não __ pouco __ muito __	não __ sim __ qual?	1 2 3 4 5
2	Pesquisar/Seleccionar paciente	não __ sim __	45 s ____	não __ poucos __ muitos __	não __ pouco __ muito __	não __ sim __ qual?	1 2 3 4 5
3	Adicionar Ferida	não __ sim __	45 s ____	não __ poucos __ muitos __	não __ pouco __ muito __	não __ sim __ qual?	1 2 3 4 5
4	Captar Fotografia	não __ sim __	30 s ____	não __ poucos __ muitos __	não __ pouco __ muito __	não __ sim __ qual?	1 2 3 4 5
5	Medir área/definir forma	não __ sim __	2:00 m ____	não __ poucos __ muitos __	não __ pouco __ muito __	não __ sim __ qual?	1 2 3 4 5
6	Preencher formulários	não __ sim __	1:30 m ____	não __ poucos __ muitos __	não __ pouco __ muito __	não __ sim __ qual?	1 2 3 4 5
7	Visualizar fotografia tirada	não __ sim __	30 s ____	não __ poucos __ muitos __	não __ pouco __ muito __	não __ sim __ qual?	1 2 3 4 5
8	Terminar Sessão	não __ sim __	30 s ____	não __ poucos __ muitos __	não __ pouco __ muito __	não __ sim __ qual?	1 2 3 4 5
9	Login e Seleccionar Paciente	não __ sim __	30 s ____	não __ poucos __ muitos __	não __ pouco __ muito __	não __ sim __ qual?	1 2 3 4 5
Tarefa	Tarefa	Completou a Tarefa?	Tempo Máximo / Tempo observado (mm:ss)	Cometeu erros?	Sentiu-se perdido?	Solicitou ajuda	Grau de facilidade observada 1 – Nada Fácil 5 – Muito Fácil

Observações

Figure B.1: Observer Guide Form

Appendix C

User Test Results

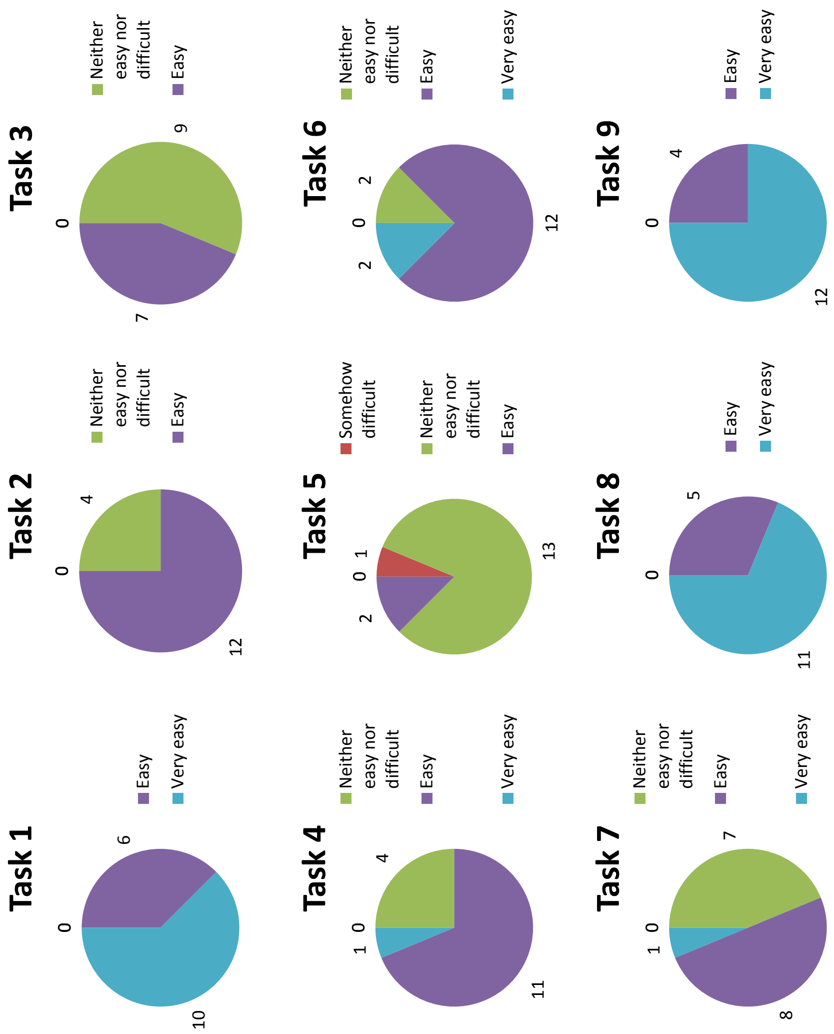


Figure C.1: User task results

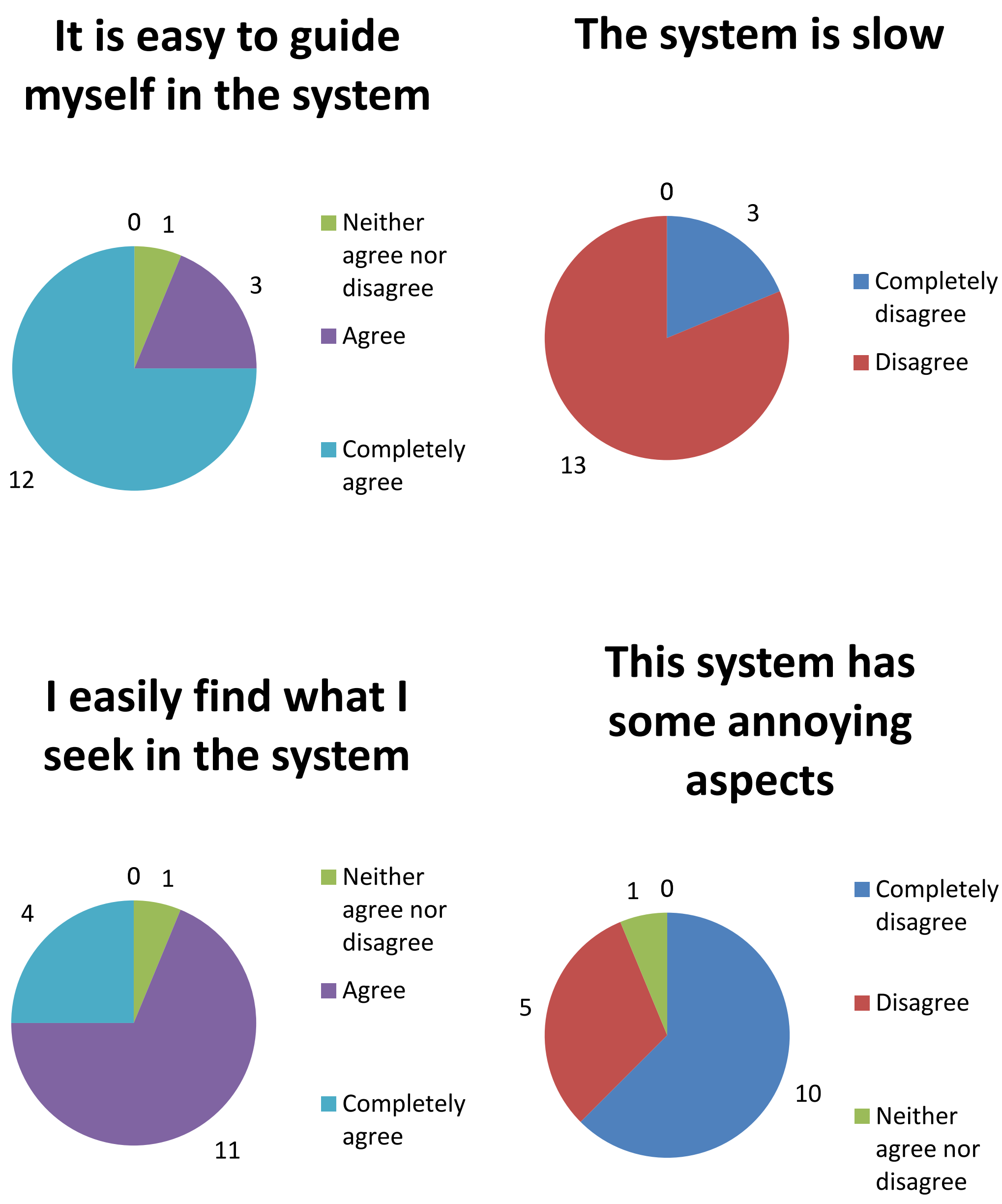


Figure C.2: Post task answers - Page 1

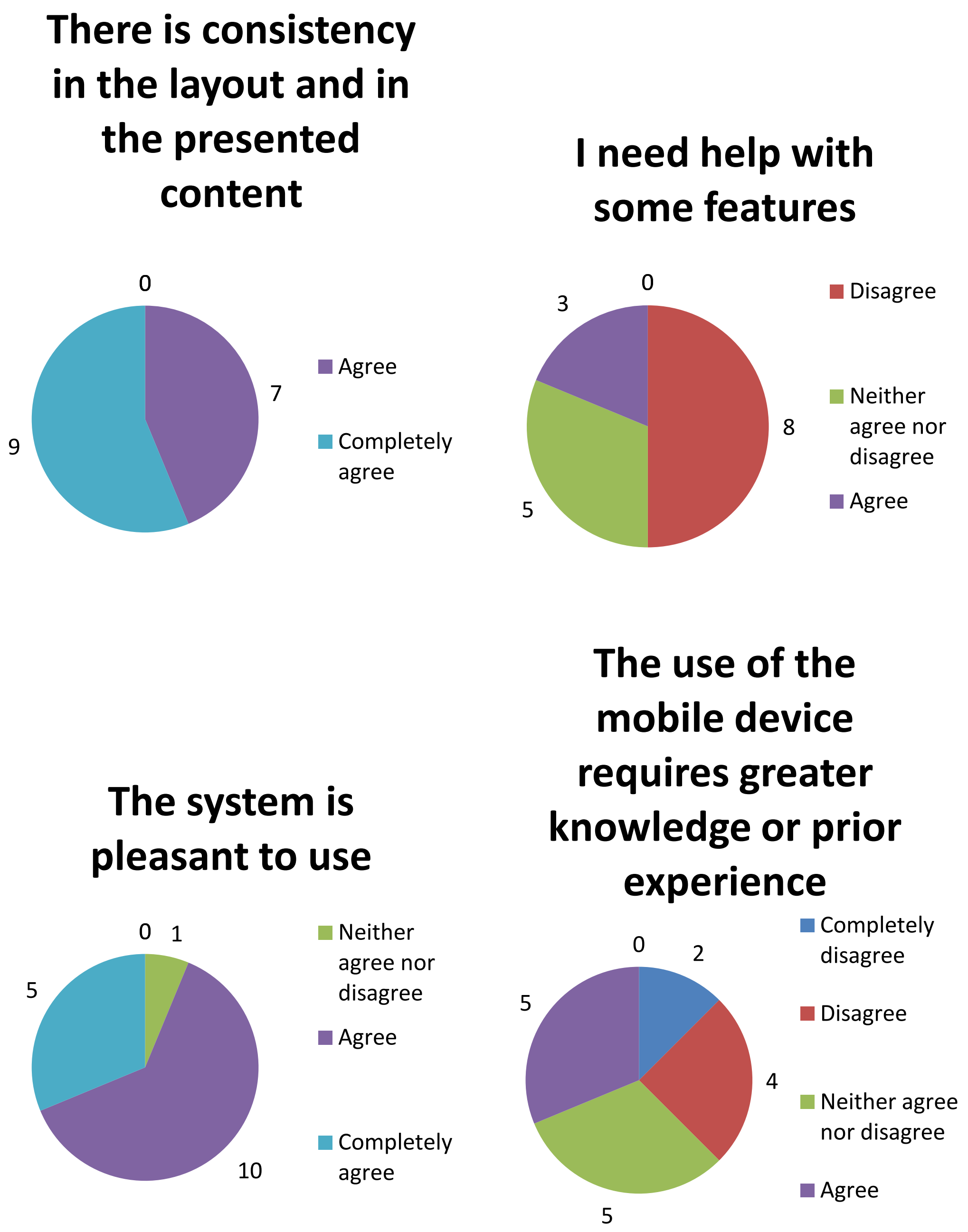


Figure C.3: Post task answers - Page 2

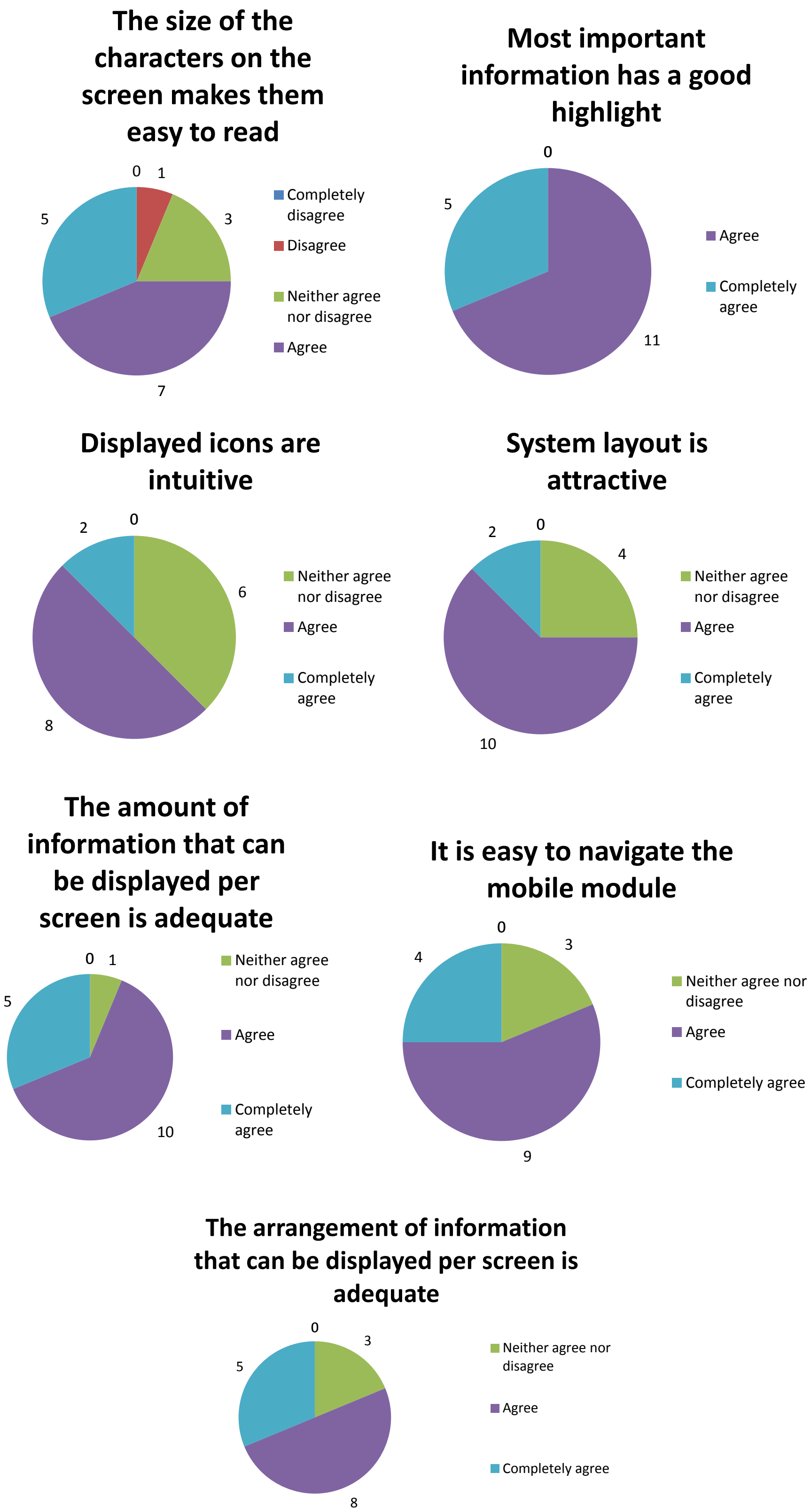


Figure C.4: Post task answers - Page 3